بِسْمِ اللهِ الرَّحْمٰنِ الرَّحِيمِ

WITH THE NAME OF GOD, ALL-MERCIFUL, MOST MERCIFUL

CALCULATED MOON BIRTHS

Determining the start and end of Ramadan by Calculated Crescent-Visibility is perfectly legitimate according to the Shari'ah

Dr Usama Hasan

Fellow, Royal Astronomical Society (UK)

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1. The Plain Truth About This Matter

قال رسول الله صلي الله عليه وسلم

صوموا لرؤيته وأفطروا لرؤيته فإن غم عليكم فاقدروا له [ثلاثين]

The Messenger of God, may God bless him and grant him peace, said:

Fast, all of you, upon seeing it [the new crescent moon] and end your fast upon seeing it; if it is obscured by cloud, then determine for it [thirty].[1]

1. Determining the beginning and end of Ramadan on the basis of calculated crescent visibility is perfectly legitimate according to the Shari'ah, as has been argued by many Muslim jurists for centuries from the earliest period of Islam (that of the *Salaf*). This is especially true now, given that calculations of new crescent visibility are extremely accurate (99-100%), and have been checked and validated repeatedly over the past few decades.

2. Some of those pro-calculation jurists derived support for this position from the saying of the Prophet ﷺ himself:

فإن غم عليكم فاقدروا له

"If it is obscured by cloud, then determine for it (the *hilal*)."

Others said that the Prophet ﷺ meant,

فإن غم عليكم فاقدروا له ثلاثين

"If it is obscured by cloud, then determine the month as thirty days."

3. As is well-known, the Shari'ah has always adapted to changing conditions: in fact, it is an obligation for *fatwas* to adapt in such a way. Given today's technology, the teaching of the Prophet ﷺ, "*Fast upon seeing it (the new crescent moon: hilal) and end your fast upon seeing it,*" must be understood in our context as: "Base your calculated lunar calendar upon the accurate, calculated visibility of the new crescent moon."

4. As for the objection that the Prophet ﷺ said that "We are an unlettered people: we do not calculate or write," this is being taken out of context, especially when we consider that Muslims have been pioneers recording and transmitting knowledge both orally and via writing, from the earliest times. Furthermore, almost every Muslim

[1] Bukhari & Muslim, in their Sahih Collections, Books on Fasting, on the authority of Abu Hurayrah, may God be pleased with him. Some narrations include the addition of "thirty"; others omit it.

community worldwide, including those who ban calculations for moonsighting, use calculated, daily Islamic prayer-times. The latter are also based on astronomical phenomena: the position of the sun in the sky. Nowadays, very few Muslims observe dawn and sunrise, shadow lengths at noon or in the afternoon, sunset and twilight for prayer-times, sufficing instead with accurate calculations, since these give the same results as visual observations. Similarly, we may confidently use accurate calculations of crescent-visibility to announce Ramadan and Eid dates in advance, knowing that this method will give the same results as naked-eye observations under clear skies.

5. As for the objection that *hilal* refers to something publicly-witnessed, this is an interesting argument but not decisive, since that is not the only meaning of the root word, *ahalla yuhillu*. Furthermore, accurate calculations of crescent-visibility are a type of public witness, especially when they give the same results as naked-eye observations.

6. As Imam Nawawi mentioned, many jurists opposed using calculations to announce Ramadan and Eid because this was an elite method known only to astronomers. It is for this reason that leading Shafi'i jurists from Ibn Surayj (and possibly Imam Shafi'i himself) to Imam Subki said that someone with astronomical knowledge could use calculations to determine Ramadan and Eid. The question must be asked: in the age of the information superhighway, with accurate astronomical knowledge being widely available, isn't the calculation no longer elite, but accessible to anyone with basic scientific training?

7. Ironically, the anti-calculation position is a literalist one based on selected hadiths; it is the "egregious mistake," (in the words of one anti-calculation writer) and not the principled, *maqasid*-based view of recent, great scholars of Hadith and Jurisprudence such as Shaykh Ahmad Shakir.

8. As for the objection that "calculations are only in people's heads," this is a dangerous, anti-science position, betraying the great Islamic scientific tradition that helped to develop the scientific method and teach it to the world. It is ironic that those who make such arguments regularly use the latest digital technology to spread their anti-science mindset, when all of this technology is built upon calculations!

9. Most jurists who oppose calculations for crescent-sighting have an inconsistent view, since they happily use calculated prayer-timetables. This is despite the fact that Islamic prayer-times are also determined by astronomical phenomena, i.e. the position of the sun in the sky, especially at the following times: dawn, sunrise, noon, sunset, twilight and midnight. Traditionally, the prayer-times were also determined by observation: dawn, sunrise, midday (noon), sunset and twilight spring to mind. For the afternoon and late afternoon prayers, it was customary to observe shadows of vertical sticks. But since almost no-one follows such old, traditional methods now, sufficing with accurate calculations because Allah has affirmed that the Sun follows precise, calculated orbits, I call upon more Muslim jurists to allow the same calculations for crescent-sighting.

2. Classical Muslim Jurists Who Allowed Calculation For Moonsighting

1. Mutarrif bin ‘Abdullah Ibn al-Shikhkhir (d. 95 H), *Tabi’i* from amongst the *Salaf*
2. Imam Shafi’i (150-204 H), according to Ibn Surayj. Others said the opposite.
3. Ibn Qutaybah (213-276 H), a Hadith expert
4. Ibn Surayj (249-306 H), a leading Shafi’i jurist
5. Muhyi l-Din Ibn ‘Arabi (558-638 H), an independent jurist
6. Ibn Daqiq al-‘Id (625-702 H), a Maliki & Shafi’i jurist
7. Taqi al-Din al-Subki (683-756 H), a leading Shafi’i jurist
8. The Isma’ilis
9. “Others”
10. Shaykh Ahmad Shakir (1309-1377 H), a leading Salafi jurist and Hadith expert

2.1 Imam Nawawi’s commentary on “If it is obscured by cloud, then determine for it.”

Imam Nawawi (631-676 H) said:

*“The People of Knowledge differed about the meaning of ‘[if it is cloudy,] then determine for it’ … **Ibn Surayj and a group, including Mutarrif bin ‘Abdullah, Ibn Qutaybah and others**, said that its meaning is: **‘Determine for it by calculation of the stations [of the moon]’** … Most jurists said that the intent is to complete thirty days … they said: It is not permissible that the intent is the calculation of the astrologers, because if the people are required to do this, it will be difficult for them because only a few individuals know how to do this …”*[2]

NB Ibn Surayj (full name: Abu l-‘Abbas Ahmad bin Muhammad bin Surayj) was a student of the Hadith expert Abu Dawud, and was a leading Shafi’i jurist: in fact, he was the Imam of the Shafi’is of his time. Another leading Shafi’i jurist, Abu Ishaq al-Shirazi, said that Ibn Surayj was greater than all the companions of Imam Shafi’i, including al-Muzani.[3]

2.2 Ibn ‘Arabi’s commentary on “If it is obscured by cloud, then determine for it.”

Muhyi l-Din Ibn ‘Arabi (558-638 H) said, “If the *hilal* of Ramadan is obscured by cloud, … I say: the experts in [celestial] movements must be asked about the station of the moon: if it is in the angle of vision, we act upon that, but if it is not in the angle of vision, we complete the term as thirty days.”[4]

He also said, “The People of Knowledge differed when the *hilal* is obscured by cloud: most of them said: the term is to be completed as thirty days … Some said: Refer to the calculation of the movements of the moon and sun. This is the position of Ibn al-Shikhkhir [Mutarrif bin ‘Abdullah, the *Tabi’i* or Follower], and I say the same.”[5]

He further said, “The hadith: *Determine*: … there are those who understood it to mean determination by the judgment of [celestial] movements, and I say the same.”[6]

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[2] Imam Nawawi, *Sharh Sahih Muslim [Commentary/ Expansion of Sahih Muslim]*, Hadith no. 1080 (*Kitab al-Sawm*: The Book of Fasting)

[3] Ahmad Muhammad Shakir, *Awa’il al-Shuhur al-‘Arabiyyah hal yajuzu shar’an ithbatuha bi l-hisab al-falaki? [The Beginnings of the Arabian Months: is it allowed by Sharia to establish them via astronomical calculation?]*, Mustafa al-Babi al-Halabi and sons, Egypt, 1358 H / 1939 CE, pp. 15-16

[4] Ibn ‘Arabi, *al-Futuhat al-Makkiyyah [The Meccan Openings]*, Dar al-Kutub al-‘Ilmiyyah, Beirut, 2011, 2:334

[5] Ibn ‘Arabi, *al-Futuhat al-Makkiyyah [The Meccan Openings]*, Dar al-Kutub al-‘Ilmiyyah, Beirut, 2011, 2:335

[6] Ibn ‘Arabi, *al-Futuhat al-Makkiyyah [The Meccan Openings]*, Dar al-Kutub al-‘Ilmiyyah, Beirut, 2011, 2:335

2.3 Imam Ibn Daqiq al-'Id supported the use of calculations

Ibn Daqiq al-'Id (625-702 H), an Imam and authority in both the Maliki and Shafi'i schools of jurisprudence, stated that if it was cloudy on the eve of Ramadan, but calculations indicated decisively that the crescent was present behind the clouds, it was obligatory to begin fasting.[7]

2.4 Imam Subki supported the use of calculations

Imam Taqi al-Din al-Subki (683-756 H) agreed with one wing of his Shafi'i tradition and said that someone with astronomical knowledge could use calculations to determine Ramadan and Eid. He furthermore stated that a report of crescent-sighting could be rejected if it was known for definite from calculations that such a sighting was impossible, because crescent-sighting reports constitute speculative (*zanni*) knowledge whilst precise calculations constitute definite (*qat'i*) knowledge.[8]

2.5 Imam Ibn Taymiyyah rejected the use of calculations because they could never be accurate enough

The following are extracts from Ibn Taymiyah (661-728 H)'s discussion of the subject, along with my comments, first published alongside a translation in 2008:[9]

To specify the location where the hilal first appears by way of calculation is not correct in the least.

Although true when it was written seven centuries ago, the last statement is simply not true in our age. The "noses" of the standard parabolic hilal-visibility curves specify, with sufficient precision for our purposes, the location on the earth where the hilal will be seen by naked eye, optical aids or a combination of the two methods.

It is not within human capability to determine specific times and locations for seeing the hilal.

This statement is also no longer true, although it certainly was when it was written, seven centuries ago. Physics and astronomy have progressed exponentially since the mediaeval times of Shaykh al-Islam. The work of Yallop, Schaefer, Ilyas, Odeh et al. is testament to this. Were Shaykh al-Islam alive today and saw what is within human capability now, I am sure that he would retract this and similar statements. I hope his followers, particularly anti-rational "traditionalists" and the official religious scholars of Saudi Arabia, will reconsider their views.

2.6 Ibn Hajar al-'Asqalani's discussion, quoting multiple authorities

Ibn Hajar al-'Asqalani (773-852 H) said:

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[7] Ibn Daqiq al-'Id, *Sharh 'Umdat al-Ahkam (Expansion on the Reliance in Rulings)*, vol. 2 p. 206, as quoted in Ahmad Shakir, pp. 10-11

[8] Taqi al-Din al-Subki, *Fatawa (Fatwas)*, Maktabat al-Quds, Cairo, vol. 1, pp. 219-220, as quoted in Ahmad Shakir, pp. 9-10

[9] *Collected Fatwas of Ibn Taymiyyah (Majmu' Fatawa Shaykh al-Islam Ibn Taymiyyah)*, ed. 'Abd al-Rahman b. Qasim and his son Muhammad, Riyadh, 1398 H, vol. 25 (vol. 5 of the Fiqh Section), pp. 98-113. English translation by Usama Hasan (1429 H / 2008 CE): (PDF) Ibn Taymiyyah on Fasting and Moonsighting.

His saying: Then determine for it. *Others took the position of a third interpretation. They said: Its meaning is:* Determine by calculating the stations [of the moon]. *This was stated by Abu l-'Abbas bin Surayj from the Shafi'is, Mutarrif bin 'Abdullah from the Tabi'in (Followers) and Ibn Qutaybah from the Hadith experts.*

Ibn 'Abdul Barr said: This is not authentic from Mutarrif. As for Ibn Qutaybah, he is not amongst those who is to be relied upon for support in matters like this. He also said: Ibn Khuwayz Mandad quoted from al-Shafi'i the view of Ibn Surayj, but what is well-known from al-Shafi'i is the view of the majority.

Ibn al-'Arabi [the Maliki jurist] quoted from Ibn Surayj that his saying, "Then determine for it" is an address to those whom God has specially favoured with this knowledge, and that "Then complete the term" is an address to the common people. Ibn al-'Arabi said: Hence, the obligation of Ramadan became different in nature for him: for some, it is obligated by calculation of [the position of] the sun and moon, and for others, by counting the number [of days]. He said: This is far from [being appropriate for] noble people.

Ibn al-Salah said: Knowledge of the stations of the moon is the knowledge of the movement of the crescents. As for knowledge of calculation [of the positions of sun and moon], this is a subtle matter in the knowledge of which only a few people are specialised. He said: The knowledge of the stations of the moon may be attained by a matter that is sensed: it is attained by anyone who observes the stars. This is what Ibn Surayj intended and stated: it is for the one with knowledge of it, specially for himself. Al-Ruyani quoted from him that he did not say that this [beginning and end of Ramadan according to calculation] was obligatory upon him, but only that it was permitted. It was also the preference of al-Qaffal and Abu l-Tayyib. As for Abu Ishaq [al-Shirazi], he quoted from Ibn Surayj in Al-Muhadhdhab [Summary of Shafi'i Jurisprudence] that fasting was mandatory on such a person in this situation.

Thus, there are multiple views about this question with respect to specifically looking into calculation and the stations [of the moon]:

- *(i) Permission, that does not suffice in place of the obligation [of seeing the crescent]*
- *(ii) Permission, that does suffice [in place of the obligation of seeing the crescent]*
- *(iii) Permission, that does suffice [in place of the obligation of seeing the crescent] for the calculator (astronomer), not the astrologer*
- *(iv) Permission for both the the calculator (astronomer) and the astrologer: for others, they may follow the opinion of the calculator (astronomer), not the astrologer*
- *(v) Permission for both the the calculator (astronomer) and the astrologer: for others, they may follow the opinion of both the calculator (astronomer) and the astrologer, unrestrictedly*

Ibn al-Sabbagh said: As for calculation, there is no disagreement amongst our companions that this is not binding upon him.

I say: Ibn al-Mundhir had quoted consensus upon this before him: he said in al-Ashrāf: Fasting the thirtieth day of Sha'ban, when the crescent has not been seen with a clear horizon [but calculation indicates it is there], is not obligatory by Consensus (Ijma') of the Nation (Ummah). It is authentic from most of the Companions and Followers that it (such

fasting) is disliked. This is how he (Ibn al-Mundhir) stated it generally, and did not differentiate between the calculator and others. Thus, whoever differentiated between them is veiled (disregarded) by the Consensus (Ijma') before him. The rest of the discussion about this will come after one chapter.[10]

قال رسول الله صلي الله عليه وسلم

إنا أمة أمية لا نكتب ولا نحسب

The Messenger of God, may God bless him and grant him peace, said:

We are an Unlettered Nation: we do not write or calculate.

[The month is like this and this, i.e. 29 or 30 days.]

His saying: 'Chapter: The Saying of the Prophet ﷺ, "We do not write or calculate".' ... By this is intended the people of Islam in his presence when he said that, applicable to most of them. Or he himself ﷺ was intended.

His saying: "We": i.e. the Arabs. It is also said: He meant himself.

His saying: "Unlettered (Ummiyyah)", with the word attributed to "Umm": it is said: He meant the nation (ummah) of the Arabs, because they did not write. Or it is attributed to mothers (ummahat), i.e. they are like newborns from their mothers [not writing or calculating]. Or it is attributed to the mother (umm) because this is usually the attribute of the woman. It is also said: They are attributed to the Mother of Towns (Umm al-Qura, i.e. Mecca).

His saying: "We do not write or calculate" is an explanation [of 'ummi'] because this is how they were. The Arabs were called 'The Unlettered Ones (Ummiyyun)' because writing was rare amongst them. God, Exalted is He, said:

هُوَ ٱلَّذِي بَعَثَ فِي ٱلۡأُمِّيِّـۧنَ رَسُولٗا مِّنۡهُمۡ ﴿الجُمُعَة﴾

He is The One Who sent amongst the Unlettered Ones,
a Messenger from amongst themselves.[11]

This is not countered by the fact that there were amongst them those who wrote and calculated, because writing was little and rare amongst them. What is intended by calculation here is that of the [positions of the] stars and their movements: they only knew very little about this. Thus, he conditioned the ruling of fasting and other matters upon seeing [the crescent], to lift the difficulty from them in the hardship of calculating such movements. The ruling about fasting continued, even if there came after them people who knew that [calculation]. The apparent context evokes total negation of conditioning the ruling upon calculations. This is clarified by his saying in the previous hadith, "If it is obscured by cloud, then complete the term as thirty"; he did not say: "... then ask the people of calculation."

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[10] Ibn Hajar al-'Asqalani, *Fath al-Bari Sharh Sahih al-Bukhari [The Creator's Opening: Commentary/Expansion of Sahih al-Bukhari]*, Hadith #1911 (*Kitab al-Sawm*: The Book of Fasting)
[11] Qur'an, *Surah al-Jumu'ah* (The Gathering, 62:2)

The wisdom in this is that if the sky is obscured by cloud, legally-responsible adults are equal in counting [the number of days], so disagreement and dissension is lifted from them.

One group of people took the position of referring to experts in [celestial] movements in this matter, and they are [the Isma'ilis]. It is quoted from some jurists that they agreed with them. Al-Baji said, "The Consensus of the Pious Predecessors (al-Salaf al-Salih) is a proof against them." Ibn Bazizah said, "This is a false position, for the Shari'ah has forbidden delving into the science of stars because it is conjecture and guesswork: there is nothing of definitude (qat') or of dominant conjecture (zann ghalib) in it. Furthermore, if this matter was linked to it, it would become very narrow because only a few people know this (science)." ...

... Ibn Battal said, "In the hadith is the lifting of having to observe the stars according to the laws of change: the reference is only the seeing of the crescents, and we have been forbidden from making matters difficult (takalluf)." There is no doubt that in observing invisible matters that can only be attained by conjectures, there is utmost difficulty (takalluf). [12]

2.7 Shaykh Ahmad Shakir

Shaykh Ahmad Shakir (1309-1377 H / 1892-1958 CE) argued powerfully for adoption of calculations to determine the Arabic months, because the Muslim nation is no longer unlettered (*ummi*) and precise calculations provide more certainty than isolated reports of crescent-sighting.

He quoted from Taqi al-Din al-Subki and Ibn Daqiq al-'Id, as given above. He also quoted from Shaykh Muhammad Mustafa al-Maraghi, President of the Supreme Sharia Court and later the Shaykh al-Azhar of the time, that a report of crescent-sighting could be rejected if it was known for definite from calculations that such a sighting was impossible.[13]

This view of al-Maraghi was later shared by a leading Saudi Hanbali/Salafi scholar, Shaykh Muhammad bin Salih bin 'Uthaymin (1347-1421 H / 1929-2001 CE).

One contemporary writer with a literalist position rather than Shakir's one that is informed by the *maqasid* (higher objectives) of the Sharia, accused Shakir of making an "egregious mistake."[14] Shakir's critic is the one making an egregious mistake with a superficial argument about *qiyas* (analogy) and *'illah* (legal cause), that is powerless in the face of Shakir's more advanced jurisprudence, that also discussed *'illah* and, when considered holistically, is based on *maqasid*.

For Shakir, crescent-sighting is a means to an end (knowledge of a new month via the presence of the new moon), whereas his critic argues that crescent-sighting is an end in itself. In any case, today's accurate calculations give the same answer as naked-eye sightings under a clear sky.

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[12] Ibn Hajar al-'Asqalani, *Fath al-Bari Sharh Sahih al-Bukhari [The Creator's Opening: Commentary/Expansion of Sahih al-Bukhari]*, Hadith #1913 (*Kitab al-Sawm*: The Book of Fasting)
[13] Ahmad Muhammad Shakir, *Awa'il al-Shuhur al-'Arabiyyah hal yajuzu shar'an ithbatuha bi l-hisab al-falaki? [The Beginnings of the Arabian Months: is it allowed by Sharia to establish them via astronomical calculation?]*, Mustafa al-Babi al-Halabi and sons, Egypt, 1358 H / 1939 CE
[14] Hamza Yusuf, *Caesarean Moon Births*, Zaytuna, 2006

3 Answers to Objections to the Use of Calculations to Replace Moonsighting

Here is a brief summary of such objections, and counter-arguments to them.

3.1 *Hilal* means a public matter, from its name

The word *hilal* is related to the raising of voices, because the root verb *ahalla yuhillu ihlal* means to exclaim loudly. The *hilal* is so-named because people would usually exclaim loudly upon first seeing the *hilal* when it appears suddenly in the sky, as though out of nowhere, as the sun's glare slowly dies down after sunset at the beginning of the lunar month. Relatedly, *istihlal* refers to the first cry of a new-born baby, by which its being alive is indicated.[15]

The term *hilal* refers to the appearance of the moon during the last two nights of the lunar month when it is visible. At the beginning of the lunar month, there is disagreement as to whether *hilal* refers to the first two or three nights of the lunar month, or even the first six nights, with the seventh night marking the end of the *hilal* phase.[16]

Although this is an interesting argument, it is not decisive, for several reasons.

Firstly, *hilal* has other meanings, including "to enter" (*ahalla yuhillu ihlal*). The related word *istihlal* also means "to become clear" (*tabayyun*). Both of these meanings are mentioned by Imam Qurtubi in his *Tafsir*.[17]

Secondly, in today's technological age, it can be argued that the knowledge of the presence and visibility of new crescent moons is known by more certainty via calculations, especially since most people do not watch the skies regularly.

Thirdly, the origin of the name *hilal* does not negate the principled arguments given by Muslim jurists for centuries for the use of calculations, especially when Allah affirms in the Qur'an repeatedly that the sun and the moon follow precise, calculated orbits.

Ibn 'Arabi said, immediately after pronouncing three times that calculations may be acted upon in this matter, "Know that the voices are only raised upon sighting, and by this it is named *hilal* …" He went on to give an inner interpretation of the validity of using calculations when cloud obscures the sky.[18] Thus, for Ibn 'Arabi, the word *hilal* signifying a public matter did not negate the validity of using calculations to determine crescent-visibility and declaring Ramadan and Eid on that basis.

Imam Ibn Taymiyyah confirmed that there is disagreement about the nature of the *hilal* based on the root meanings of its name. He stated in his *Fatawa (Fatwas)*:

The people have disputed about the "hilal": does this name apply to an object that appears in the sky even though no-one sees it? Or is it only known as the hilal when people see it (hatta yastahilla bihi l-nas) and know of it? There are two views on this in the school of Ahmad and others.[19]

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[15] Imam al-Qurtubi, *Tafsir*, *Surah al-Baqarah* (The Heifer, 2:189)
[16] Imam al-Qurtubi, *Tafsir*, *Surah al-Baqarah* (The Heifer, 2:189)
[17] Imam al-Qurtubi, *Tafsir*, *Surah al-Baqarah* (The Heifer, 2:189)
[18] Ibn 'Arabi, *al-Futuhat al-Makkiyyah [The Meccan Openings]*, Dar al-Kutub al-'Ilmiyyah, Beirut, 2011, 2:335
[19] *Collected Fatwas of Ibn Taymiyyah (Majmu' Fatawa Shaykh al-Islam Ibn Taymiyyah)*, ed. 'Abd al-Rahman b. Qasim and his son Muhammad, Riyadh, 1398 H, vol. 25 (vol. 5 of the Fiqh Section), pp. 98-113. English translation by Usama Hasan (1429 H / 2008 CE): (PDF) Ibn Taymiyyah on Fasting and Moonsighting. As I

3.2 The Prophet ﷺ said: We are an unlettered (*ummi*) nation: we do not calculate or write

As has been quoted from Ibn Hajar above, Muslim authorities have given several interpretations of this hadith. These include that the Prophet was referring to himself only, or to the Arabs of his time, since they were not experts in calculation and writing. There have been recent authorities who still quote this hadith to outlaw calculations, but this argument would imply that writing should be outlawed as well for Muslims.[20] Furthermore, as Ahmad Shakir and others have argued, the Arabs and Muslims are no longer unlettered in this sense, and in fact were pioneers of mathematics, astronomy and compiling voluminous written works, so that this condition no longer applies to Muslims.

3.3 "Witnessing the month" can only be done via seeing the *hilal*

فَمَن شَهِدَ مِنكُمُ ٱلشَّهۡرَ فَلۡيَصُمۡهُ
البَقَرَة

Whoever witnesses the month [of Ramadan] amongst you, must fast it.[21]

This is a very weak argument advanced by a contemporary writer[22], because this Qur'anic phrase refers to being alive, adult, sane and healthy, such that the Ramadan fast is obligatory, as mentioned by the major commentators. Clearly, the vast majority of Muslims never actually see the *hilal* of Ramadan, but suffice with news and decisions from other people.

3.4 "Enter houses from their doors"

۞ يَسۡـَٔلُونَكَ عَنِ ٱلۡأَهِلَّةِۖ قُلۡ هِيَ مَوَٰقِيتُ لِلنَّاسِ وَٱلۡحَجِّۗ
وَلَيۡسَ ٱلۡبِرُّ بِأَن تَأۡتُواْ ٱلۡبُيُوتَ مِن ظُهُورِهَا
وَلَٰكِنَّ ٱلۡبِرَّ مَنِ ٱتَّقَىٰۗ
وَأۡتُواْ ٱلۡبُيُوتَ مِنۡ أَبۡوَٰبِهَاۚ
وَٱتَّقُواْ ٱللَّهَ لَعَلَّكُمۡ تُفۡلِحُونَ
١٨٩ البَقَرَة

They ask you [O Prophet] about the crescent moons.
Say: they are time-markers for people, and for the Pilgrimage.
It is not piety that ye enter houses from the rear,
But piety is to eschew (evil).
Enter houses from their doors,
And be conscious of God: perhaps ye will attain success.[23]

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stated in my footnote to that translation: Surely, we can state that the correct view in the modern world is this: that the *hilal* exists even if no-one sees it. In the past, it was possible to doubt this because sighting was the only reliable method of determining whether or not it was there in the sky. However, based on the latest astronomical calculations that enable us to predict *hilal*-visibility with a high degree of precision, we can confidently say whether or not the *hilal* is visible in the sky from any given location on earth, even if no-one sees it. This has massive implications for the entire debate about moonsighting and constructing an accurate, calculated lunar calendar based on *hilal*-visibility.

[20] الحساب الفلكي وإثبات أوائل الشهور | موقع الشيخ يوسف القرضاوي Yusuf al-Qaradawi, *Astronomical Calculation and Establishing the Beginnings of the Months [Arabic]*, accessed 16/2/2006

[21] Qur'an, *Surah al-Baqarah* (The Heifer, 2:185)

[22] Hamza Yusuf, *Caesarean Moon Births*, Zaytuna, 2006

[23] Qur'an, *Surah al-Baqarah* (The Heifer, 2:189)

This is another weak argument advanced by a contemporary writer, that the command to enter houses from their front doors, and not their rear doors, metaphorically means to enter the lunar months by crescent-sighting and not by calculation.[24] As Tabari and Zamakhshari state, the pagan Arabs would avoid front doors during the Pilgrimage (Hajj) season, and hence this verse was revealed. Although Zamakhshari affirms that the second part of this verse may be related to the first in the sense of "concentrate on worship, the way to piety, and do not ask unnecessary questions, such as about the crescent moons," this has nothing to do with calculations. This argument certainly does not invalidate the principled arguments given by Muslim jurists for centuries for the use of calculations to determine the lunar months.

3.5 Calculations are only "in someone's head"

This is another weak argument advanced by a contemporary writer,[25] and is an affront and insult to the vast, Islamic mathematical and astronomical tradition: the astronomers of the Dar al-Hikmah, Bayruni, Ibn al-Shatir, Battani, 'Abdul Rahman al-Sufi and others until our times: Ilyas, Shaukat, Afzal, Odeh and others. Allah affirms in the Qur'an repeatedly that the sun and the moon follow precise, calculated orbits. The irony is that contemporary Muslims making such anti-calculation arguments use the latest technology and fly around the world, etc., activities that are entirely based on calculations.

This approach also holds back reconciliation of Islamic theology and science, and poisons Muslim minds against the astonishing progress of science and technology, and endeavour in which Muslims once led the world. For this reason, we present the next section.

4 A Brief History of Moonsighting Calculations

This section is summarised from a presentation given by Dr Steve Bell of Her Majesty's Nautical Almanac Office, then hosted at the Rutherford Appleton Laboratory, on *Islamic Astronomy and Moonsighting* at the Muslim World League, London, 8th September 2007.

4.1 Medieval and modern methods

Earliest (ancient) observations led to the following rules in the medieval period:

1. The age of the moon (since astronomical birth) needed to be more than 24 hours in temperate latitudes, for visibility. At the Equator, the age could be 16-25 hours. At a Latitude of 30º, it needed to be 17-33 hours.

2. The Babylonians stipulated a lag time (moonset after sunset) of over 48 minutes.

3. Medieval Islamic methods stipulated a lag time of over 48 minutes, plus ARCL (arc of light or *qaws al-nur*) being more than 11.25º.

[24] Hamza Yusuf, *Caesarean Moon Births*, Zaytuna, 2006
[25] Hamza Yusuf, *Caesarean Moon Births*, Zaytuna, 2006

4. Modern observations show that the lag time for crescent-sighting should be in the range 22-84 minutes.

5. NB The lunar month lasts about 29.5 days. If we round this up to 30 days for ease of calculation and divide 24 hours by 30, we get 48 minutes. Since the moon will be in approximately the same position in the sky after a month, moonrise and moonset vary by an average of about 48 minutes every day, becoming earlier each day.

Medieval and modern methods use(d) the following quantities to help calculate crescent-visibility:

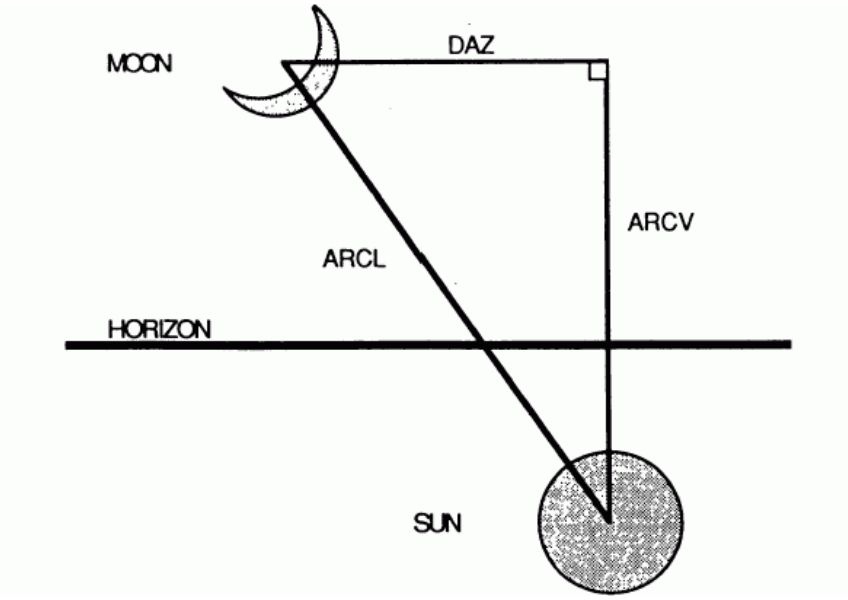

Figure 1: Calculating Crescent Visibility

In Figure 1: Calculating Crescent Visibility, the sun is depicted below the horizon (20 minutes after sunset is roughly the optimal time to see the crescent moon), with the crescent moon above it. The following quantities are referenced:

- Arc of light (ARCL) قوس النور
- Arc of vision (ARCV) قوس الرؤية
- Relative azimuth (DAZ) الفرق في الزاوية السمتية (الأفقية)

NB Ibn Taymiyyah was familiar with these terms, mentioning the arc of light (*qaws al-nur*) and arc of vision (*qaws al-ru'yah*) in his discussion of moonsighting.

Modern examples utilising the above terms include the methods of Maunder (1911), Bruin (1977) and the Indian Astronomical Ephemeris (1996).

In 1931, the French astronomer Danjon proposed, on the basis of experiments with mirrors and astronomical observations, that the arc of vision had to be a minimum of 7° for the crescent moon to be visible. This is known as the Danjon limit.

4.2 Modern methods

The following factors are used for crescent-sighting predictions:

1. Calculated positions of Sun & Moon
2. Calculated rise/set times
3. A knowledge of twilight
4. Key quantities for calculating first sighting
5. An algorithm to predict first sighting
6. Generate global and local predictions
7. Ability to improve the predictions

4.3 Modern prediction criteria

Using the above factors, astronomers over the past century or so developed the following criteria, based on physics and observations of the new crescent moon:

1. Fotheringham (1910): ARCV > f(DAZ) e.g. f(0º) = 12º, f(20º) = 10º

2. Maunder (1911): ARCV > f(DAZ) e.g. f(0º) = 11º, f(20º) = 6º

3. Ilyas (1984): ARCV > f(DAZ) e.g. f(0º) = 10º, f(20º) = 7º

4. Yallop (1980's): ARCV > f(w = crescent width)

5. Schaefer (1988) did not publish the details of his method, but his calculations gave similar answers to those of Yallop and Ilyas.

6. Odeh (2004), based on several hundred observations:
   ARCV > f(w), with a Danjon limit[26] of 6.4°

4.4 HMNAO's method: the Yallop Criterion

The HMNA method uses the following quantities and calculations:

- Sunset time, T_s
- Moonset time, T_m
  - ➔ Calculate Lag time = T_m - T_s
  - ➔ Calculate best time (from Bruin's visibility curves) = T_s + 4/9 (Lag time)
- Get topocentric altitude of Moon, a_m
- Get depression of Sun, d_s
  - ➔ Calculate ARCV = $a_m + d_s$

[26] The Danjon limit is a minimum angle of reflection that is required for sunlight to reflect off the moon and be visible on earth. It is based on astronomical observations experiments with mirrors.

HMNAO then uses Yallop's Criterion to calculate a quantity q that indicates the degree of crescent-visibility:

$q = 0.1 * (\text{ARCV} - 11.8371 - 6.3226 * w + 0.7319 * w^2 - 0.1018\ w^3)$

where:

ARCV is the sum of the altitude of the Moon and the depression of the Sun, and

w is the topocentric width of the crescent in arcminutes.

Yallop's criterion is interpreted as follows, based on thousands of confirmed sightings and non-sightings of the crescent moon, to give crescent visibility:

A – easily visible q > 0.216
B – visible in perfect conditions q > -0.014
C – may need optical assistance q > -0.16
D – Will need optical assistance q > -0.232
E – Not visible with telescope q > -0.293
F – Beyond Danjon limit q <= -0.293 (corresponding to a Danjon limit of 8°)

4.5 Crescent-visibility curves

These categories (A-F) give the familiar HMNAO crescent-visibility curves using six colours (including white), such as the following one for Ramadan 1428 H (2007 CE):

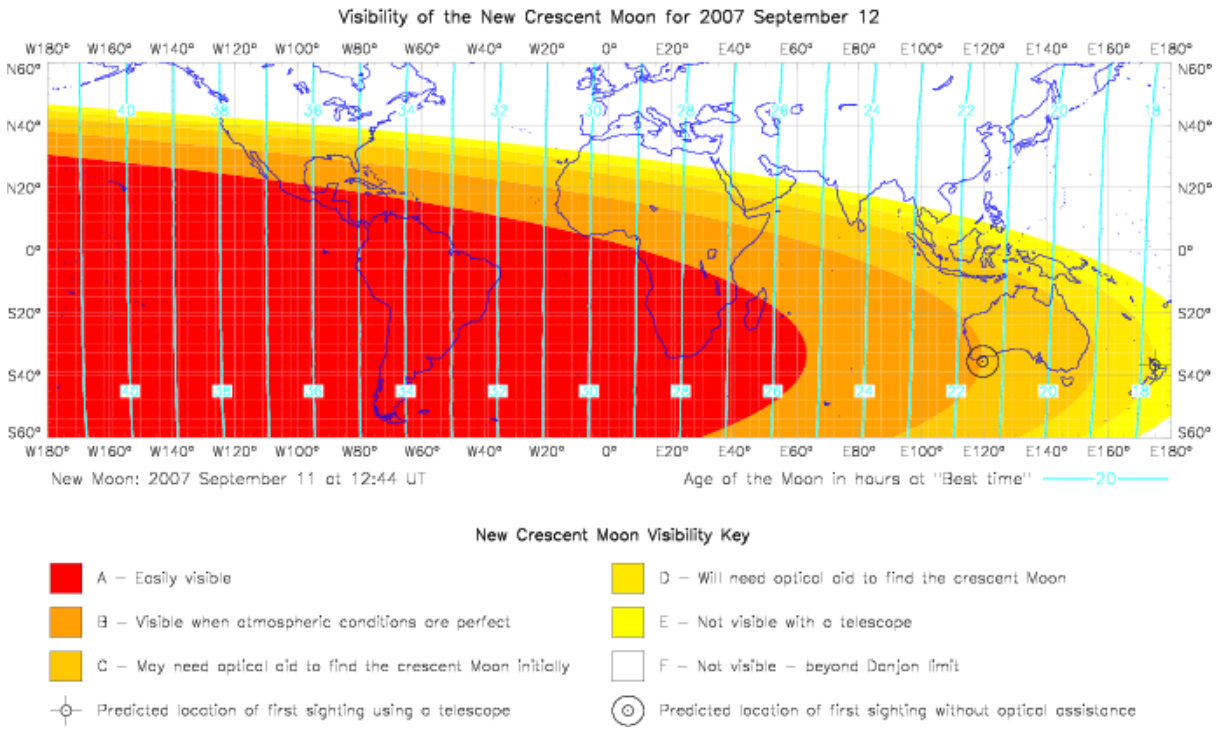

Figure 2: Crescent-visibility curves for Ramadan 1429 H / 2007 CE

NB Odeh's visibility curves are slightly simpler, since they only use five categories.

4.6 World record crescent sightings: naked-eye, telescope & CCD-imaging

As of 2007, the record naked-eye sighting of a young crescent moon was about 15 hours, whilst the record with an optical telescope was about 12 hours.

Over the past two decades, sensitive CCD (charge-coupled device) cameras have been developed that are able to image the new crescent moon at much younger ages, requiring an Arc of Vision of only 4°. CCD cameras are even able to image the new crescent before sunset.[27] Some CCD cameras use infrared light, which is outside the visible spectrum.[28]

Those who insist on visual sightings will need to answer whether, and to what extent, spectacles, binoculars, optical telescopes and CCD imaging qualify as visual sightings. Or do the latter have to be naked-eye sightings only?

5 Using Calculations for Crescent-Sighting, just as for Islamic Prayer Times

Most jurists who oppose calculations for crescent-sighting have an inconsistent view, since they happily use calculated prayer-timetables. This is despite the fact that Islamic prayer-times are also determined by astronomical phenomena, i.e. the position of the sun in the sky, especially at the following times: dawn, sunrise, noon, sunset, twilight and midnight.

Traditionally, the prayer-times were also determined by observation: dawn, sunrise, midday (noon), sunset and twilight spring to mind. For the afternoon and late afternoon prayers, it was customary to observe shadows of vertical sticks. But since almost no-one follows such old, traditional methods now, sufficing with accurate calculations because Allah has affirmed that the Sun follows precise, calculated orbits, I call upon more Muslim jurists to allow the same calculations for crescent-sighting.

The literalist insistence on visual sighting of the crescent moon forgets that the same argument could be applied to Islamic prayer times: for example, the beginning time of fasting and of the dawn prayer (*salat al-fajr*) is conditional upon the dawn "becoming clear or apparent" (*tabayyun*):

وَكُلُواْ وَٱشۡرَبُواْ حَتَّىٰ يَتَبَيَّنَ لَكُمُ ٱلۡخَيۡطُ ٱلۡأَبۡيَضُ مِنَ ٱلۡخَيۡطِ ٱلۡأَسۡوَدِ مِنَ ٱلۡفَجۡرِۖ ثُمَّ أَتِمُّواْ ٱلصِّيَامَ إِلَى ٱلَّيۡلِ البَقَرَة

Eat and drink, until it becomes apparent to you:
the white thread, from the black thread, of dawn.
Then, complete the fast until night.[29]

Obviously, dawn becoming apparent is a visual phenomenon, as is nightfall at sunset. Why do the jurists who insist on visual observation of the crescent moon not insist on daily visual observations of dawn, sunrise and sunset?

I use both calculations and observations for daily prayer-times, and for moonsighting. The two methods give the same result, in terms of timing. The experience is different, but this is not a reason to make matters difficult by mandating observation and banning calculation.

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[27] P. Mahasena et al., *CCD observation of daylight crescent moon at Bosscha observatory*, The 6th International Conference on Mathematics and Natural Sciences, Institute of Physics Conference Series (2019), IOP Publishing, https://iopscience.iop.org/article/10.1088/1742-6596/1127/1/012049/pdf

[28] Martin Elsässer, Crescent imaging explained, 1st July 2013, Mondatlas.de: Crescent imaging explained

[29] Qur'an, *Surah al-Baqarah* (The Heifer, 2:187)