Proceedings of the IIIT Lunar Calendar Conference

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Edited by Imad-ad-Dean Ahmad

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The Editor

Imad-ad-Dean Ahmad

Imad-ad-Dean Ahmad is a Ph.D. astronomer who has been actively involved in the issue of moonsightings and the Islamic calendar since the 1980's. Born in 1948 of Palestinian parents, Dr. Ahmad was raised in Pennsylvania. He graduated *cum laude* from Harvard in 1970 and in 1975 obtained a Ph.D. in astrophysics from the University of Arizona. Dr. Ahmad has done postdoctoral work in astronomy at Harvard, the University of Maryland, and under contract to Goddard Space Flight Center and for private firms. He is currently president of his own research firm, Imad-ad-Dean, Inc.

Since the mid-1980s Dr. Ahmad has worked primarily in the area of Islamic studies, building on his lifetime interest in religion and science. In 1987, he was the organizer of the IIIT Islamic Lunar Calendar Conference. Currently, he is president of the Minaret of Freedom Institute, an Islamic free-market think tank and an adjunct professor at Johns Hopkins University's School for Advanced International Studies and at the University of Maryland, where he teaches an honors course on "Religion and Progress: Islamic Science, Politics, and Economics." He also teaches classes in religion and ethics at the Islamic Weekend School at Tilden Jr. High School in Bethesda. In addition, he is president of the Islamic-American Zakat Foundation, serves as Muslim Chaplain at the Clifton T. Perkins Hospital in Jessup, Maryland, and leads a Qur'an study group at the Dar-adh-Dhikr mosque in Bethesda.

In 1992, Dr. Ahmad published his first book, *Signs in the Heavens: A Muslim Astronomer's Perspective on Religion and Science.* He presented a talk on this subject at the 1994 Vatican Conference on the Inspiration of Astronomical Phenomena on World Culture sponsored by the Vatican Observatory. His other books are *Islam and the Discovery of Freedom*, an annotated version of Rose Wilder Lane's classic on the history of liberty, and *Islam and the West: A Dialog*, in which he co-edited a series of roundtable discussions between American experts on Islam and Muslim intelletuals and activists.

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Foreword

Consciousness of time is an essential part of a Muslim's consciousness of being on earth. A Muslim is aware of the temporal parameters of birth and death and the future of the Hereafter. Between the birth-death extremities, time is the medium of the Islamicity of a Muslim. For a Muslim, temporal existence is not an amorphous concept, rather, it is a means of performing the most essential duties of an Islamic life. *Ṣalāh* (worship) and *ṣiyām* (fasting) are rendered impossible without the awareness and accurate measurement of time.

When God created the planetary system, He made the accurate measurement of time possible. People around the globe use the sun and the moon as their foci for the measurement of time. The ingenuity of considering time as a function of regular planetary body movement has stood the test of time. In fact, the gigantic strides in technology in recent time has not questioned the validity of this idea. What has happened though, is that the technological revolution has provided far more accurate tools in observing and measuring the movement of planetary bodies which translates into greater accuracy in time measurement. Similarly, a technological revolution in communication has made the transfer of the knowledge of time determination accessible to a degree that could not be thought possible earlier in human history.

Greater accuracy in time measurement and expanding world communication poses a challenge to the implementation of the *Sharī'ah*. Since the performance of Islamic duties rests on time observation and measurement, how does today's greater accuracy affect the formulation and observance of the *Sharī'ah*? The most important challenge facing today's Muslims is how to implement the *Sharī'ah*—formulated in a prescientific world—according methods implemented in a society undergoing scientific revolution. For example, the *'Īd* (festival) days at the end of *Ramaḍān* and the 10th of *Dhu al Ḥijjah* are determined by the sighting of the crescent moon that marks the beginning of a new lunar month. Both days are occasions for Muslim celebrations wherever they may be. In recent times, ironically, both occasions have become points of division and disunity in the world Muslim community, as different communities and even sub-communities use varying means for determining their occurrences. Instead of generating a sense of unity and purpose, these days have become catalysts of tension and division in the Muslim community, especially with Muslim minorities in the West. Some of the blame must be born by Muslims who are reluctant to deal with present reality. It is no longer possible for communities to celebrate the *'Īd* irrespective of another distant community. Communication has shrunk the world and made movement and exchange of information too easy to be ignored.

This conference set itself the task of approaching and uncovering the issues of time observation and measurement in the scientific age. In particular, it attempted to formulate the juridical (*shar'ī*) questions of the observation and measurement of time in astronomical terms. From there, the conference had to open the discussion for formulating a *shar'ī* measurement of time in a scientific age. The conference actually did all this and more. It clarified the issues and distinguished itself as the first step toward the final solution. The papers in this volume testify to the high standard maintained in the conference. In fact, the overwhelming success of this conference prepared the ground for an international conference which further probed the solution of this vexing problem. The results of that conference are summarized in the Afterword. It is with pride and honor that the IIIT presents this volume to mark the achievement of the conference.

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Preface

This volume is the proceedings of the lunar calendar conference held at the International Institute of Islamic Thought (IIIT) auditorium in Herndon, VA, in June 1987. Sponsored by the IIIT, it was attended by over two dozen participants principally from North America.

The purpose of the conference was to bring together the latest scientific facts with the questions germane to Islamic calendar construction. Considerable effort was exerted to limit discussion to scientific aspects of the problem and to avoid prejudicing the outcome with disagreements among the *fuqahā'* (Muslim jurists) regarding purely juridical questions. Nonetheless, the scientific results will be of great interest to the *fuqahā'*.

The conference was a success in terms of the high quality of the scientific papers presented and in the fact that the participants were able to announce a unanimous statement on the scientific questions (the final chapter). One of the most important conclusions reached at the conference is that scientific agreement alone is insufficient to formulate a successful global Islamic calendar—some conventions regarding matters which are not questions of scientific fact must also be adopted. By following the conclusions presented in the statement that concludes this volume, the conventions used by the many Islamic communities can be made consistent and free of scientific errors while still allowing differences. It is our hope that the scientific principles adopted at this conference will be supplemented by the adoption of a single set of conventions by the *fuqahā'* at a conference in the near future.

I am pleased to thank Dr. Ṭāhā Jābir al 'Alwānī of IIIT for his support and enthusiasm for this project. I am grateful to Dr. Sayyid Muhammad Syeed, Director of Academic Outreach at the Institute for assuming responsibility of coordinating the efforts between myself and the IIIT. I am also thankful to Muhammad Bashir of IIIT for his hard work with the nuts and bolts of making the conference run smoothly, and to my wife, Frances Eddy, for her secretarial assistance in editing these proceedings. Thanks are due to all the participants for their efforts in the struggle to attain knowledge. Above all, I am grateful to Allah (be He glorified and exalted) for creating the moon-earth-sun system and giving us the capacity to make use of it. I pray that He aid us in fulfilling that capacity in the best way.

Imad-ad-Dean Ahmad
Conference Coordinator
Shawwāl 1408 A.H. / June 1988 A.C.

Contents

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Introductory Remarks

Ṭāhā J. al 'Alwānī

Praise be to Allah, the Cherisher and Sustainer of the Worlds. The Blessings and Peace of Allah be upon Muhammad, the last of His messengers, and on his followers until the Day of Judgement.

Peace, compassion, and blessings of God be upon all of you.

It gives me pleasure to welcome this assembly of distinguished scholars on behalf of the International Institute of Islamic Thought, which is honored by the convening of this important scientific seminar. We thank you all for accepting our invitation and acknowledge your research contributions to this seminar, and we recognize the inconveniences that most of you underwent to get here. I express special appreciation to Dr. Imad-ad-Dean Ahmad, who shouldered the burden of coordinating this symposium—the fruits of which are eagerly anticipated by specialists in the field—from the time it was conceived until it became a reality.

This symposium deals with an important topic. While recognizing the scientific undertakings and excellent research presented by outstanding participants, we stress the importance of scientific commentary and discussion throughout the proceedings. Honest and open discussion is indispensable to finding solutions for the major issues addressed by the symposium and is vital to arriving at a unanimously approved scientific formulation—convincing to specialists in the field—of an Islamic calendar. Such a calendar is vital to the organization of the life of the *ummah*, making it active and bringing it out of stagnation. Man has discovered the path of progress only after his recognition of the importance of measuring time. Civilization rests on three pillars: man, resources, and the calculation of time. If a nation fails to give appropriate recognition to any of the three, it is doomed to lapse into backwardness and decadence. God the Exalted has entrusted man with the mandate of vicegerency on the earth so that he may build, seek truth, do justice, diffuse good, and appreciate the beauty of the vast universe.

God has willed that there be cycles of power and civilization. At a particular juncture of history, our planet beheld the rise of the best nation evolved for mankind—an *ummah* justly balanced, a witness over the peoples, a civilization that fused progress, truth, righteousness, and beauty in a manner unmatched before or since in the history of humanity. The *ummah* claimed no monopoly on any of these values, nor did it deny them to other peoples. Scientific secrecy was unknown at the zenith of its society. On the contrary, the *ummah's* science, culture, and achievements were accessible to all nations. The *ummah* made its schools, universities, and health available to other peoples to such an extent that the enlightenment enjoyed by its civilization spread across the globe. Subsequently, the *ummah* slipped into a vortex of crises and was stricken by intellectual malaise. The result has been cultural stagnation, scientific backwardness, and social decadence until, in this century, the *ummah* has come to rest at its lowest point. Certainly the *ummah* has lost much, but the world has lost even more by the *ummah*'s decadence and backwardness. It is inconceivable that such losses can be remedied without the *ummah* regaining its vitality and legitimacy in today's world community.

We are gathered here to lay an important brick in the *ummah's* new edifice—a scientifically developed, Islamic calendar worthy of approval by all Muslims. This will afford real civilizational dimensions and finality to the hitherto unfinished argument over an Islamic calendar that was begun early in Islamic history. This time there will be the addition of further scientific data and technological insight, permeated by the spirituality of Islam—a spirituality that relates everything to the Creator of life and humanity, thereby protecting man from vanity, knowledge from deviation, and civilization from pitfalls. Within this well-balanced civilizational framework we gather today—Muslims and non-Muslims, technicians and social scientists—to discuss this important issue. With the purpose of expounding the significance of our meeting and our target, I would like to present the following points.

The Qur'an was revealed to an Arab prophet in an Arab environment. The earliest vanguard of Islam were Arabs. They were generally thought to be capable of neither calculation nor writing—though the discovery in the peninsula of ancient relics and evidence from certain Qur'anic texts obviously suggest the need to amend this theory. Nevertheless, the Arabs definitely did not achieve any degree of systematic knowledge in the science of astronomy. It is probable that they identified a number of stars, classified them, verified their times of rising and setting, and adopted their own methods of drawing astronomical diagrams. They also identified certain planets and followed the movements of the moon, and related all of these things to issues of human life. Furthermore, they were highly concerned with calculating the passage of years—even if only in a primitive fashion, due to total dependence on observation with the naked eye. The calendars left by the Makkans, as well as other relics from the days of *Jāhiliyyah* (the pre-Islamic era), reveal their knowledge of the lunar year. It seems, however, that due to their unenlightenment they subjected calculation of time to their own interests, like fools who waste their knowledge by being oblivious of its worth. Thus, for instance, they adopted the method known as *al nasi'* (transposing), thereby mishandling the calendar by progression, regression, omission, or inclusion of dates at will. Though there is abundant mention of *al nasi'* in exegesis, we may safely state that it implies the mishandling of "time issues" in favor of self-interest. The Arabs then attained a method of time calculation with which to relate lunar and solar months. At some point, they surmised that calculation of their pilgrimages and feasts on the basis of the lunar year would cause these to occur alternately in summer and winter, resulting in disadvantages in both travel and trade. Deciding that adherence to the lunar calendar would damage their interests, the Arabs preferred to harmonize their religious and trade interests by adopting the solar calendar. But because the solar year exceeds the lunar by 10 days, 21.2 hours, they had also to adopt a "leap year" system. They calculated this leap year as consisting of 13 months and rescheduled pilgrimage seasons and the sacred (*ḥarām*) months in accordance with times of breezy, fine weather. Thus pilgrimage, for instance, occurred one year in *Dhu al Ḥijjah*, another year in *Ṣafar*. The Arabs imagined that, by so doing, they were coordinating their commercial interests with their religious events and recreational travel in a way that would ensure the occurrence of all in days of mild weather. I shall not elaborate further on the details of the customs related to this issue, since these are better described in pre-Islamic Arabic poetry and narrative.

Islam has established a relationship between man and astronomy in a way that affects a type of ideological education for humanity. There are Qur'anic verses that call for contemplation of the greatness of the Creator as reflected in the universe, the extent of which is beyond human imagination. Man beholds stars in their orbits traveling across the heavens with impeccable precision in their times of rising and setting and their dates of appearance and disappearance. Planets revolve about them with perfect timing. The whole scene is one in which man senses his diminutiveness, as well as the bounty and the glory of creation. He certainly observes the astonishing precision of the movements of celestial bodies, the vast number of which defy his ability to count despite all his science and skill in calculation. Modern astronomy, we all know, describes clusters of galaxies, each consisting of billions of solar systems, traveling in the endlessness of space at astounding speeds in every direction—a glorious spectacle that reflects the infinite majesty of the Creator and demands our contemplation. Man scans aspects of this glory whenever darkness casts its mantle over the earth, aspects represented by the pulsating stars adorning the firmament to which he turns his vision once and again, never to witness a flaw. He beholds the sunrise every morning and sunset every evening. He witnesses the rising and setting of the moon in changing times, yet still with unfailing precision. There are stars in the firmament that act as beacons to guide him on land and sea:

وَهُوَ الَّذِي جَعَلَ لَكُمُ النُّجُومَ لِتَهْتَدُوا بِهَا فِي ظُلُمَاتِ الْبَرِّ وَالْبَحْرِ قَدْ فَصَّلْنَا الايَاتِ لِقَوْمٍ يَعْلَمُونَ

It is He Who maketh the stars (as beacons) for you, that ye may guide yourselves with their help through the dark spaces of land and seas. (6:97)

وَسَخَّرَ لَكُمُ اللَّيْلَ وَالنَّهَارَ وَالشَّمْسَ وَالْقَمَرَ وَالنُّجُومُ مُسَخَّرَاتٌ بِأَمْرِهِ إِنَّ فِي ذَلِكَ لَايَاتٍ لِقَوْمٍ يَعْقِلُونَ

And the stars are in subjection by His Command: verily in this are signs for men who are wise. (16:12)

فَلا أُقْسِمُ بِمَوَاقِعِ النُّجُومِ وَإِنَّهُ لَقَسَمٌ لَوْ تَعْلَمُونَ عَظِيمٌ

Furthermore, I call to witness the placing of starts (in the firmament). And that is a mighty adjuration, if ye but knew. (56:75-76)

وَالشَّمْسَ وَالْقَمَرَ كُلٌّ فِي فَلَكٍ يَسْبَحُونَ

And the sun and the moon: all (the celestial bodies) swim along, each in its orbit (21:33)

Man's sense of wonder at the glory of his Creator deepens when he studies the star systems with their revolving planets, the galaxies each with billions of such systems, the galactic clusters—many of them still beyond the reach of modern astronomy in spite of its sophisticated methods of measurement (including measurement of the speed of light) and its technically advanced telescopes. All this cosmic structure is sustained with a flawlessness that defies the very imagination, all without pillars or girders:

خَلَقَ السَّمَاوَاتِ بِغَيْرِ عَمَدٍ تَرَوْنَهَا وَأَلْقَى فِي الارْضِ رَوَاسِيَ

> He created the Heavens without any pillars that ye can see; He set on the earth mountains standing firm . . . (31:10)

This grandeur inspired scholars of ontology (*tawḥīd*) to draw attention to the profound significance of Qur'anic verses stating astronomical facts as expressive of the glory and unity of the Creator:

إِنَّ فِي خَلْقِ السَّمَاوَاتِ وَالارْضِ وَاخْتِلافِ اللَّيْلِ وَالنَّهَارِ لآيَاتٍ لاولِي الالْبَابِ

> Behold! In the creation of the heavens and the earth and the alternation of night and day, there are indeed Signs for men of understanding. (3:190)

Ontological and astronomical studies are often interwoven in a way that realizes certain aspects of the ideological orientation of man. This point is authenticated in the words of such scholars as al Ghazālī, al Rāzī, Ibn Ḥazm al Andalusī, and 'Aḍud al Dīn al 'Ījī, to name a few. Al Muṭṭahhir ibn Ṭāhir al Maqdisī summed up clearly the ontological theory that the movements of celestial bodies in their orbits necessitate the existence of a Mover of limitless power. The consistency of such movement is a clue that time does not in any way affect this Mover—that He is permanent, unlimited in might and ability, imperishable, incorruptible, totally other than His creatures, perfect, and unseizable by slumber or sleep.

The worship enjoined by Islam is regulated by both solar and lunar timing. Worship (*ṣalāh*), for instance, is performed on the basis of solar time:

أَقِمْ الصَّلاةَ لِدُلُوكِ الشَّمْسِ إِلَى غَسَقِ اللَّيْلِ وَقُرْآنَ الْفَجْرِ

> Establish regular prayers at the sun's decline till the darkness of the night, and the Qur'an at dawn. (17:78)

وَسَبِّحْ بِحَمْدِ رَبِّكَ قَبْلَ طُلُوعِ الشَّمْسِ وَقَبْلَ غُرُوبِهَا

> And celebrate the praises of thy Lord, before the rising of the sun and before its setting. (20:130)

Pilgrimage (*ḥajj*), fasting (*ṣawm*), and almsgiving (*zakāh*) are all regulated by lunar time:

يَسْأَلُونَكَ عَنِ الأهِلَّةِ قُلْ هِيَ مَوَاقِيتُ لِلنَّاسِ وَالْحَجِّ

> They ask thee concerning the new moons; say: They are but signs to make fixed periods of time in the (affairs of) men and for pilgrimage. (2:189)

شَهْرُ رَمَضَانَ الَّذِي أُنزِلَ فِيهِ الْقُرْآنُ هُدًى لِلنَّاسِ وَبَيِّنَاتٍ مِنَ الْهُدَى وَالْفُرْقَانِ فَمَنْ
شَهِدَ مِنكُمُ الشَّهْرَ فَلْيَصُمْهُ

> Ramadan is the (month) in which was sent down the Qur'an as a guide to Mankind, also clear (signs) for guidance and judgment (between right and wrong). So everyone of you who is present (at his home) during the month should spend it in fasting. (2:185)

Zakāh is connected with the lunar year. There are Islamic personal laws that are based on lunar months and years, such as a woman's waiting period (*'iddah*) of three menstruations after final breaking-off of marital relations.

وَالْمُطَلَّقَاتُ يَتَرَبَّصْنَ بِأَنفُسِهِنَّ ثَلاثَةَ قُرُوءٍ

> Divorced women shall wait concerning themselves for three monthly periods. (2:228)

وَالْوَالِدَاتُ يُرْضِعْنَ أَوْلادَهُنَّ حَوْلَيْنِ كَامِلَيْنِ

> The mothers shall give suck to their offspring for two whole years . . . (2:233)

Thus Islam has given calculation and precision of timing special importance as one of the characteristics of Islamic civilization. From its ver beginnings, Islam provided principles for establishment of a precise calendar with which to uproot the deceitful practices of *jāhiliyyah*. Following ar illustrative instances. The number of months was finalized:

إِنَّ عِدَّةَ الشُّهُورِ عِندَ اللَّهِ اثْنَا عَشَرَ شَهْرًا فِي كِتَابِ اللَّهِ يَوْمَ خَلَقَ السَّمَاوَاتِ وَالأرْضَ
مِنْهَا أَرْبَعَةٌ حُرُمٌ ذَلِكَ الدِّينُ الْقَيِّمُ فَلا تَظْلِمُوا فِيهِنَّ أَنفُسَكُمْ وَقَاتِلُوا الْمُشْرِكِينَ

> The number of months in the sight of Allah is twelve (in a year), so ordained by Him the day He created the Heavens and the earth; of them

> four are sacred: that is the straight usage. So wrong not yourselves therein, and fight the pagans. (9:36)

Al Nasī' was abolished:

إِنَّمَا النَّسِيءُ زِيَادَةٌ فِي الْكُفْرِ يُضَلُّ بِهِ الَّذِينَ كَفَرُوا يُحِلُّونَهُ عَامًا وَيُحَرِّمُونَهُ عَامًا لِّيُوَاطِئُوا عِدَّةَ مَا حَرَّمَ اللَّهُ فَيُحِلُّوا مَا حَرَّمَ اللَّهُ زُيِّنَ لَهُمْ سُوءُ أَعْمَالِهِمْ وَاللَّهُ لَا يَهْدِي الْقَوْمَ الْكَافِرِينَ

> Verily the transporting (of a prohibited month) is an addition to unbelief: the unbelievers are led to wrong thereby, for they make it lawful one year and forbidden another year, in order to adjust the number of months forbidden by Allah and make such forbidden ones lawful. The evil of their course seems pleasing to them. But Allah guides not those who reject faith. (9:37)

The Prophet said, "The number of months as ordained by Allah is twelve (in a year), of which four are sacred, three sequential (*Dhu al Qi'dah, Dhu al Ḥijjah, Muḥarram*) and one, *Rajab,* between *Jumādā al 'Ūlā and Sha'bān.*" The Prophet also proclaimed, "*al Nasī'* is an addition to unbelief."

Because of the close relationship between *fiqh* and astronomy, and in the hope that a joint seminar of *fuqahā'* and astronomers will be convened in the near future, we should here expound the attitudes of classical and modern *fuqahā'* toward specific astronomical issues related to *fiqh*—such as the legal status of *ru'yah* (witnessing of the new moon), i.e., whether it is an act of worship or a mere legal tenant. There is also the concept among the *fuqahā'* of contradiction between *ru'yah* and astronomical calculation. I shall elaborate on the factors underlying these attitudes and will end with suggested solutions to some problems.

The question is, why have classical—and in general also modern—*fuqahā'* rejected, or at least been suspicious of, astronomical calculations? The answer is two-sided: classical and modern. The classical *fuqahā'* have based their position on the following assumptions:

1. That certitude of the *ru'yah,* or its equivalent, is realized by either a legal or a factual indication. The factual is eyewitness testimony; the legal is counting 30 days for the lunar month. These are seen as the only sure ways of ascertaining the beginning of a lunar month.
2. That dependence on calculation alone would end in *al nasī',* a practice adopted in the *jāhiliyyah* and rejected by Islam.

3. That astronomical calculation would result in a shortening of the lunar month, since astronomers (so the *fuqahā'* contend) always calculate the lunar month as consisting of 29 days, 12 hours, 44 minutes. The *fuqaha'* calculate it as either 29 or 30 days, a fact leading to the conviction that their difference with the astronomers is basically one of lunar month definition
4. That astronomical calculations are based on mere speculation about the crescent and not on its actual presence after sunset.
5. That, to astronomers, the common commencement of the lunar month occurs at the moment immediately following termination of the moon's fourth quarter. This, the *fuqaha'* argue, could occur at any moment—day or night. Such calculation is insupportable to them since, according to the *Sharī'ah*, the commencement of the lunar month is signaled solely by the *ru'yah* of the new moon on the western horizon in favorable weather conditions by an eyewitness after termination of the fourth lunar quarter. Many among the classical *fuqahā'* hold that the legal grounds for the initiation of fasting (*ṣiyām*) Ramadan should be either the *ru'yah* of the new moon on the 29th day of the lunar month of Sha'ban or—if this is not feasible—the counting of 30 days for a full month of Sha'ban. This, to them, is an instance of basing an injunction on a legal cause. A legally acceptable cause should never be overlooked in favor of a legally insupportable one such as that utilized by astronomers. The substitution should, beyond doubt, better fulfill legal requirements.
6. The *fuqahā'* have always tended to confuse astronomical instructional calculation (*'ilm al ḥisāb al falakī wa al ta'līmī*), as the discipline was designated up to the seventh century A.H., with astrology (*'ilm al hay'ah al raṣdī*, study of the signs of the Zodiac) , which is concerned with the influence of planetary movement on people and events. There are several historical reasons for this view among the classical *fuqahā'*—reasons related to the development of various disciplines and philosophies, as well as to methods of research characteristics of their votaries. Because of this, the *fuqahā'* fear adoption of astrology or astrological statements—a matter categorically rejected by *Sharī'ah*.
7. The classical *fuqahā'* tend to follow strictly what is specified by *Sharī'ah* as principles underlying an enjoined act of worship. Any disregard of such binding principles in one area, such as *ru'yah*—they hold—would justify similar conduct in another, such as testimony in court.
8. The classical *fuqahā'* prefer more feasible forms of performance of legal matters: here, eyewitness sighting of the new moon. For these reasons, the classical *fuqahā'* have—with near consensus among them—rejected astronomical calculation and its findings. Ibn Taymiyah, as well as other jurists, asserted this view and regarded as illicit dependence on calculation in matters pertaining to *ṣawm* (fasting) and *fiṭr* (breaking of fasting). This view is further attested by many of Ibn Taymiyah's *fatawā* (juridical judgements). He confirmed the consensus among jurists of the first three centuries A.H.

concerning this issue and stated that the first legal statements in favor of calculation were made by a very limited number of jurists after the year 300 A.H. He and other jurists well versed in the issue invariably commented unfavorably on those dissenting from their view, the most eminent of whom was Ibn Surayh.

Such were the reasons I offered for the classical *fuqahā's* rejection of astronomical calculation in relation to the *ru'yah*. Underlying the attitudes of the modern *fuqahā'* are factors similar to those observed above, with the addition of:

1. Complete, or near complete, ignorance of astronomy—especially its latest development—the rule being that people reject that with which they are unfamiliar.
2. The rejection of astronomical calculation has become, over the course of centuries, part of the culture and traditions of the *ummah*.
3. Contradictions, whether real or illusory, between the outcome of calculation and *ru'yah*, due to a host of factors, many of which have been investigated by you.
4. The fact that the *ummah* is at present torn into nation states, with affiliations and political concerns that influence the issue.
5. Disagreement over the beginnings and endings of lunar months among those countries that do adopt calculation.

Following are some suggestions that may be useful in resolving the issue.

1. To render a certain amount of astronomical information familiar to students of Islamic sciences as part of their studies in order to assist in improving the image of astronomy.
2. To seek an agreement between the *fuqaha'* and the astronomers about the definition of the terms "beginning" and "end" of the lunar month, as well as about the determination—and exchange—of terminology in this specific area of study.
3. Then to attempt establishment of a comprehensive lunar calendar that is in keeping with the mutually approved definitions to be universally adopted.
4. To render juridical concepts related to the issue understandable to astronomers and to get them to grasp the applicational importance of astronomical findings in legal questions.
5. Astronomers—or a certain faction thereof—should discontinue hasty popularization of some of their findings, since haste may involve pitfalls caused by flaws in methodology and means of research.
6. To reject sorcery, imposture, and hearsay about signs of the Zodiac and reading the future, all of which have been much popularized by the mass media. The adverse effects of such practices on the minds of people should be

exposed and should be shown to have no connection whatsoever with astronomy.

7. To defuse pressures unrelated to legal and scientific aspects of the controversy—such as the argument for *ummah's* unity—and to concentrate on technical aspects.

Many of you have inquired into whether *ru'yah* that decides the commencement or termination of *ṣawm* (fasting) is an actual act of worship or a mere legal rationale. The *ru'yah* in this case is the legal rationale of a definite act of worship, viz. *ṣawm*. According to the Ḥadīth, "Fast at the sighting of [the new moon] and terminate [the month of] fasting at the sighting of it." Similar to this is the *ru'yah* of the declining sun from its zenith until the times for the fullest darkness as an indication of the times for the enjoined prayers. "Establish regular prayers at the sun's decline." Thus the decline of the sun signals times of prayer, while sighting of the new moon of Ramaḍān signals the onset of *ṣawm*. Any method of the *ru'yah* in a legal issue that is beyond the possibility of error suffices for a decision of the related legal issue. Priority, however, should be given to adoption of the methods specified by the *Sharī'ah*. To develop, improve, and protect such methods from erring is the duty of every Muslim. Their underlying wisdom should be consistently clarified. I should state that, were consistent contradiction between *ru'yah* and astronomical calculation to be proven beyond a doubt, jurists would face a dilemma. Islamic jurisprudence has related many legal questions to *ru'yah* (literally, "seeing"). It is encountered in most areas of *fiqh*, e.g. *mu'āmalāt* (daily transactions), criminal law, and enjoined acts of worship. Thus, for instance, rejection of evidence given by a witness who meets legal requirements and who is of flawless character is dangerous because it implies a nullification of the very principle of legal evidence by witnesses, or at least weakens its application in an arena in which it is crucial.

Juridically, there is nothing against utilizing astronomical methods to investigate the genuineness of a ru'yah. If eyewitness testimony is confirmed by astronomical calculations, the situation would be one of aggregate clues from different sources validating the issue at hand. If, on the other hand, the *ru'yah* witness hesitates and withdraws his evidence, or if the evidence is proven to be imaginary or obviously false, the issue is decided by nullification of that evidence. But to categorically reject the testimony of an eyewitness solely on grounds of incongruence with astronomical calculations is unreasonable and has its hazards. Nevertheless, a questionnaire answered by eyewitnesses may assist in determination of the authenticity or falsehood of their evidence. Whoever discusses this issue in writing or in public speech should do so bearing in mind its specific framework and the civilizational perspective within which it should be scrutinized. A practice that should be revived is that of collective *ru'yah* in Muslim population centers and in Muslim countries generally, in order to accumulate evidence from trustworthy eyewitnesses in areas where visibility of the new moon is more probable.

The science of astronomy is regarded by Muslims with the highest esteem. Muhammad ibn Jābir al Baṭṭanī—one of the top twenty astronomers known in the history of human civilization—said:

> [Astronomy] has a well-earned place among disciplines for its tremendous share in helping man calculate years and months, provide accurate time, mark seasons, observe increase and decrease in duration of days and nights, watch locations and eclipses of the sun and the moon, witness the movements of planets in their faring in alternating places and signs. Much more may be added by it through study and scrutiny that invariably leads to further proof and knowledge of the greatness, wisdom, and power of the Creator.

Astronomy, like other disciplines, was nurtured by Islamic faith and civilization, in the shade of altars of worship. Muslims—whether Arabs, Persians, or Indians—preserved whatever studies were there in the legacy. They even translated astronomical works from other nations, such as the Greeks and Romans. They speculated, studied, and contributed to astronomy. They introduced various methods into the discipline until it matured at the hands of its numerous Muslim votaries and emerged as a discipline with its own branches, methodology, and relationships to such other disciplines as ontology, *fiqh*, and medicine. It is unanimously recognized by specialists that it was Muslims who corrected most errors perpetrated by other nations in astronomical considerations up to the dawn of the European renaissance. They developed astronomy and contributed outstanding additions to it, including new inferences in various matters as well as new methods. In fact, Muslims were the first to utilize the inductive method in astronomy and to sift the discipline from the fraudulence of astrology. Had the *ummah* been spared the lapse that struck it, had the intellectual malaise not prevailed over its entire life, had its present scientific backwardness not existed, man might have established space science long ago.

Disciplines branch off to keep abreast of intellectual advancement and civilizational progress. One discipline often divides into totally new sections, of which some develop into disciplines of their own, a cycle that often recurs. Any student of human legacy may observe that, in the past, certain disciplines or parts thereof had appellations that were later discarded in favor of other titles in the framework of other disciplines as a result of the development of human knowledge. An outstanding instance is the science that is the topic of our symposium. It was first known in our legacy as the science of "the contour" (*'ilm al hay'ah*). Then, after several centuries, its specialists used four different designations: "the science of stars" (*'ilm al nujūm*), "star craft" (*ṣinā'at al nujūm*), "the science of astrology" (*'ilm al tanjīm*), and "trade of astrology" (*ṣinā'at al tanjīm*). To scholars of the legacy, astronomy had two major divisions:

- knowledge of the special contours, their complexities and natures; and
- knowledge of the influence of planets and their signs on man. A specialist in the discipline was called an "astronomer" (*falakī*), "connoisseur" (*ahkami*) astrologer (*munajjim*), or "master of contours" (*'ālim al hay'ah*).

Al Farabi (d. 339 A.H. / 950 A.C.), in his classification of disciplines, divided (*'ilm al hay'ah*) into two parts. The first includes astronomical studies that cover methodology and tools utilized in studying orbits and movements of stars, as well as weather forecasting and time measurement. The second part is mathematical and involves the methodology of establishing calendars and collecting astronomical data by mathematical calculation on the basis of well-established astronomical theories of time calculation to ensure maximum precision. Al Farabi stated that whatever data from watching the firmament relates to the future are more appropriately included in studies of the human psyche. If we accept this suggestion from al Farabi, such study should be related to the present-day science of psychology. Al Farabi asserted that mathematical astronomy (*'ilm al hay'ah al ḥisābī*) is the part of the discipline that is worthy of the designation "science." The other part, the study of stars, is nearer to conjecture and divination by birds and stones. Al Farabi divided the studies of "informative" astronomy (*'ilm al nujūm al ta'līmī*) into three sections, the third being concerned with the study of inhabited and uninhabited regions and the division of the former into areas. The same section included the study of the influence of movements of the stars and earth on times and places of rising and setting and on differences in duration of days. Ibn Rushd (d. 595 A.H./ 1198 A.C.) designated the part of astronomy studying movements of the stars as "experimental" (*ṣinā'at al nujūm al tajrībiyyah*). He termed the mathematical part "informative" astronomy (*ṣinā'at al nujūm al ta'līmiyyah*). Astronomy, as we have mentioned, developed at the hands of Muslim scholars and had relationships with other disciplines. Then their development of it came to a standstill due to the intellectual malaise of the *ummah*, the stagnation of its science and creativity, the transformation of the Muslim mind from innovation and scholarship to deterioration and mimicry. The last of the Muslim votaries of astronomy may have been Fakhr al Din al Razi (d. 606 A.H./ 1228 A.C.), regarded as one of the last encyclopedic scholars, who excelled in many disciplines and stamped each with everlasting influence.

But after an age of academic achievement, the Muslim intellect staggered in every field of knowledge. Matters of astronomy became so mixed with those of astrology that the layman could hardly differentiate the two. Jurists limited their academic activities primarily to areas of direct interest to them. Academe became mere memorization of the contents of books as means to the realization of material gain and the occupation of coveted posts. There appeared individuals combining knowledge of the fundamentals of astronomy with astrology. They did not use their mathematical charts to study the stars, the planets, their movements and times of cycles, or to collect calendrical data; instead, they used their mathematical charts to study what pagan nations claimed about the influence of planets—singly or combined—on man, civilization, and nations. They indulged in fortune telling. It is well known that all heavenly religions are averse to such claims and practices, which are not in keeping with reality and scientific fact. As a result, some claimants to knowledge of *fiqh* condemned astronomy as a prohibited discipline and warned against adopting its findings. Such acceptance, they argued, would be tantamount to accepting the frauds of astrology. This lead Muslims to revert in matters related to worship—particularly the *ru'yah* of new moons for the commencement of lunar months—to dependence on eyewitness testimony or on 30-days counting to the exclusion of every other method.

In the European intellectual revival of the Age of Enlightenment, Western scholars started to translate man's legacy in astronomy, including the Arab's contribution, into their own native languages, thereby initiating a new development cycle for astronomy. Today, we are witnessing dramatic progress in the discipline. Fields of astronomical studies have widened in a way that only you as specialists would know about. Certainly we have not invited you to this seminar in order to lecture you in your own specialization. We invited you in order to avail ourselves of your knowledge and experience dealing with one of the important issues facing the *ummah*.

Our primary duty is to try to contribute to the present renaissance of civilization and knowledge and to disseminate the benefits thereof for the good of mankind. It is the highest calling of intellectuals to resist the backwardness, poverty, illiteracy, and sickness that afflict two-thirds of the world's population so as to help humanity overcome these maladies. To achieve such purposes, a firm cultural and intellectual foundation as well as favorable conditions are required to make possible the transfer of civilization to backward areas of the world and their help their people's progress. This will help preserve the present civilization and protect it from factors of decadence that have already started to infect it.

Having studied the current condition of the *ummah*, we have come to the conclusion that it suffers from a paralyzing intellectual malaise, sparking cultural maladies that have left the *ummah* in an abyss of backwardness. In that abyss, the individual has lost his self-respect and is no longer looked upon as the creature entrusted with vicegerency on the earth. As a backward individual, he has lost all sense of the value of time as a factor in production. There is, as well, the disappointing failure to utilize his resources, which is all too obvious to observers. Any attempt to put the *ummah* back on the road of civilization and progress should be founded on correcting this intellectual malaise and its sinister impact on culture and knowledge. Next, priority should be given to asserting the value of the individual's esteem for his role and his human rights. Important also is realization of the value of time—of precise time calculation and its use in establishing an Islamic calendar.

The establishment of such a calendar is a cultural issue concerned not only with religious affairs but also with restoration of the *ummah's* awareness of the factor of time and calculation in building up a civilization. The *ummah*, we remember, was at one time the builder of world civilization and the bearer of its banner. To establish the Islamic calendar on firm ground we need to, first, formulate specific recommendations on the methodology and second, study the major stumbling blocks to establishing the calendar and utilizing it. Those stumbling blocks—or issues—may be summarized as follows. They should be studied thoroughly.

1. Contradictions in the statements and calculations of astronomers. This includes disagreement on the meaning of terminology, differences in methods of calculation, and differences in means and tools of observation and follow up. These should be studied with a view to identifying causes of inadequacy to reach correct and consistent results.
2. Occasional discrepancies between calculations and facts, including errors in times of rising and setting and in places and degrees of latitude and longitude.
3. Unifying methods of calculation and realizing agreement among astronomers about the least erroneous of those methods.
4. Finding ways to harmonize the findings of calculation with eyewitness testimony.
5. Generating the *ummah's* awareness of the importance of establishing an Islamic calendar and the required methodology to achieve this purpose.
6. Finding ways to overcome the intellectual, cultural, and juridical obstacles to utilization of the calendar and to adoption of the methodology leading to its establishment.

We realize that *ru'yah* of the new moon is not in itself an act of worship and that neither is observing the movement of the sun by shadow lengths to ascertain prayer times. We all calculate hours for work without objection because the *ummah* is convinced of the precision of such calculation and because it does not contradict reality. Accumulating scientific data required for the establishment of a comprehensive calendar and agreeing about such data and methods of its collection are the major issues we hope you will resolve. If this hope is fulfilled, then an Islamic calendar will only be a question of time.

LUNAR CALENDAR CONFERENCE OVERVIEW

Imad-ad-Dean Ahmad

In recent times the Islamic world has fallen into confusion every time the date of an *'Id* festival or the fast must be set. This year Saudi Arabia began its fast before the commencement of the new moon, by any scientifically acceptable definition. In America different groups began their fast on different dates. Yet, although three different definitions of the new moon were used, all groups managed to end on the same date.

Much of the confusion is due to misunderstanding scientific terms or failing to appreciate the accuracy and precision of scientific models. For example, why should people who closely follow scientific calculations of solar positions and setting for the purpose of determining the daily prayers completely reject the scientific calculations of moonset—even to the point of accepting allegations of lunar sightings after the moonset time? The conference that we are holding today and tomorrow is primarily a meeting of astronomers, both Muslim and non-Muslim, who are dedicated to clarifying the issues involved with determining the Islamic lunar calendar by presenting the most up-to-date information on the matters of orbital calculation. Confusion that arises from disagreements over *fiqh* and the interpretation of the meanings of hadith are better left to a future joint conference of *fuqaha* and Muslim astronomers.

The first part of verse 189 of *Surat al Baqarah* has been translated by A. Yusuf Ali in the following manner: "They ask thee concerning the new moons. Say, they are but signs to mark fixed periods of time in (the affairs of) men, and for pilgrimage." Thus the new moon has no mystic significance—the moon's phases are only a clock. Similarly, the Prophet (peace be upon him) chastised those followers who said that the sun darkened because of the death of his infant son Ibrahim, with the admonition that the sun and moon are signs of Allah and do not eclipse for the death of human beings.[1]

The question that has caused so much confusion among Muslims is how to read this clock Allah has placed in the sky—especially as regards the beginning and end of Ramadan. By definition the astronomical new moon is when the moon lines up between the earth and sun (defined as the time when the celestial longitude of the moon and sun are the same). At that time the moon cannot be seen from earth because it is too close to the sun and is lost in the glare of the daylight scattered from the sun by the air. It is not until many hours later that the new moon can be seen.

It takes the moon 29 1/2 days to travel its orbit around the sun. Thus the month can be 29 or 30 days. (Many *ahadith* support this well-established fact.) The Prophet warned his companions that they were an unlettered people who could "neither write nor count," and therefore they must prefer to sight the moon rather than calculate its position—although, if the day were cloudy, they could calculate it by waiting 30 days from the previous new moon.[2] Later, when Islamic civilization flourished and the Muslims could not only count and write but had invented spherical astronomy, the scholars were able to calculate the time when a new moon could be sighted. Today, we can calculate the time of new moon sighting to within a few hours (for most places on the earth), and the exact time of the astronomical new moon more accurately than watches are generally maintained.

BACKGROUND

One requirement which must be imposed not only on scientific models, but also on juristic decisions, is the requirement of logical consistency. While it is not for a scientific assembly to dictate to Muslims whether to use the time of calculated sighting (traditional definition of new moon) or the time of actual conjunction (astronomical definition of new moon) to set their calendars, Muslims must in any case use the same method to calculate the end of Ramadan as the beginning. Otherwise, the month may end up 28 or 31 days, or it may end up 29 when it should be 30, or 30 when it should be 29.

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1. Imam Muslim, *Sahih*, vol 2, trans. Abdul Hamid Sadiqui (Lahore: Muhammad Ashraf, 1976), in Book 6 (Kitab al-Sawm), Chapter 406, hadith no. 2376, 526 .

2. Imam Muslim, *Sahih*, vol 2, trans. Abdul Hamid Sadiqui (Lahore: Muhammad Ashraf, 1976), in Book 6 (Kitab al-Sawm), Chapter 406, hadith no. 2378, 527.

The first day of Ramadan of this year provided an opportunity for observers on the east coast of the United States to resolve a dispute as to when the first time of sightability is. By the "moonset lag criterion,"[3] the new moon of Ramadan had a better than even chance of being seen from the American eastern seaboard on the evening of Tuesday, April 29. By contrast, Yallop argued that, on the basis of a generalization of "an ancient Babylonian rule," it was "impossible to make the observation at more easterly longitudes" than 86.25 degrees West.[4] However, the new moon was observed from a suburb of Washington, D.C. some 9 degrees to the east,[5] as well as from a number of other eastern locations.[6]

THE ZONE OF UNCERTAINTY

Among the many points that we hope this conference will clarify are the distinction between conjunction and sightability, the impossibility of sighting a moon that has set, and the difficulties of sighting a moon that sets soon after the sun. But if there is one point that I think has been most underappreciated by the astronomical community, it is the fact that calculation of sightability is a probabilistic endeavor. The algorithm which Yallop advocated has been shown to be overly conservative as a hard limit on earliest sightabilty.[7] We must emphasize the fact that while a line can be drawn east of which sightability from the ground is impossible due to the Danjon effect and another line can be drawn west of which sightability is limited only by local weather conditions, between these lines is a wide region where many variables including the quality of the observer's eyes plays a role in detectability. Having accepted this fact, we may then proceed to try to model, as best as we can, the factors that determine observability within this zone.

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3. Mohammad Ilyas, *A Modern Guide to Astronomical Calculations of Islamic Calendar, Times, and Qibla* (Kuala Lampur: Berita, 1984).

4. B. D. Yallop, RGO Astron. Info. Sheet no. 50, 1987.

5. B. E. Schaefer, private communication, 1987.

6. L. E. Doggett, and P. K. Seidelman, abstract for IIIT Lunar Calendar Conference, 1987.

7. Yallop, RGO Astron. Info. Sheet no. 50.

THE EXAMPLE OF DHU AL HIJJAH 1407 (1987)

In the table below I give the moonset lag behind sunset in Makkah, Saudi Arabia, for days following astronomical new moon (conjunction) near the beginning of Dhu al Hijjah 1407 (1987) and an estimation of the probability of sighting under good conditions. The estimation of the probability is calculated assuming that Ilyas' stated errors are standard deviations.[8] Notice that with the moonset lag calculation there is some uncertainty about the correct date in Makkah. On Sunday, July 26, 1987, the moon set approximately 41 minutes after the sun in Makkah. Sighting this moon would be very difficult, but not quite impossible. Thus Monday would be the earliest date for the first of Dhu al Hijjah. By coincidence, dating by means of conjunction gives us the same result. Conjunction took place at 12:37 a.m. standard time in the Saudi time zone on July 26. Thus, on the system based on conjunction, the first day of Dhu al Hijjah in Saudi Arabia was Monday, July 27 and the *'Id* would then be on August 5. Neither system would permit the first of Dhu al Hijjah to begin on Sunday, July 26 or earlier, since the moon set before the sun on the previous evening.

Table 1

Date	Moonset Lag in Makkah	Probability of Sighting (Estimated)
July 25th	----------	impossible
July 26th	41 minutes	< 0.05
July 27th	111 minutes	certain

In the past it was held that each community must use calculations (or sightings) for its own area. Of course, a legitimate sighting in Makkah would imply that a legitimate sighting should be possible in Washington because sunset occurs 8 hours later there, although at very high latitudes the moon may not be sighted at all. Some are now claiming that the availability of high speed communication makes this restriction obsolete. We emphasize, however, that ANY SIGHTING GIVING AN *'ID* EARLIER THAN AUGUST 5 IN SAUDI ARABIA DESERVES DISMISSAL OUT OF HAND. It would have been either incorrect or else a miracle. Neither a

8. Ilyas, *A Modern Guide to Astronomical Calculations of Islamic Calendar, Times, and Qibla.*

false sighting nor a miracle serves the clock purpose the Qur'an gives to the new moon.

August 5 would be the date of *'Id al Adha* in Makkah based on conjunction. If one requires sighting, then it is only the earliest possible date. Since Saudi Arabia falls in the zone of uncertainty, a decision by the *fuqaha* to rely on actual sightability from the ground would mean that an attempt to actually sight the moon is necessary to resolve the uncertainty.

We note that if it were allowed that an observation anywhere on earth before dawn in Saudi Arabia should set the date of the new month, then an August 5 *'Id* is a certainty, since even Yallop's conservative calculations[9] predict observability over the Atlantic ocean at 20:48 UT that same evening (comfortably before the Saudi dawn).

EXPECTATIONS

The papers which shall be presented for the duration of the conference reflect the state of the art of calculations of the times of conjunction and of visibility and the errors associated with each. Among the topics addressed are uncertainties due to meteorological conditions, instrumental factors, altitude of observation, and visual acuity of the observer. We hope to achieve a scientific consensus on the algorithms for, and the accuracy of, methods for determining the date and time of the new moon, both from conjunction and from sighting by an ideal observer under arbitrary terrestrial conditions, as well as the errors associated with those determinations.

Our conference should provide scholars with the scientific facts needed to issue a *fatwa*. Within this scope we may issue a consensus-of-the-conference statement on any scientific question on which unanimous agreement may be found. The result should permit the calculation of an Islamic calendar corresponding to whatever criteria the religious scholars may choose to adopt for the definition of the new moon, be it birth (the astronomical conjunction) , moonset after conjunction, or visibility under some set of prescribed conditions.

9. Yallop, RGO Astron. Info. Sheet no. 50.

State of the Art of Islamic (Lunar) Calendar Calculations: An Overview

Mohammad Ilyas

Abstract

A brief survey of the Islamic development of astronomy, especially in the context of lunar calendrical science, is followed by a discussion of the underlying basis of an international Islamic calendar. A brief account of the improvements to the scientific prediction of a new lunar crescent together with the nature of global visibility and related international lunar date lines are given. The paper provides an overall view of the progress on an international Islamic calendar.

Introduction

The Islamic calendar is a serious manifestation of astronomy involving several related disciplines—dynamical and optical physics, biophysics, and, of course, mathematical and spherical astronomy—therefore, astronomy presented a special challenge to the Muslims. Indeed, Muslims dominated scientific development for 700 years. According to George Sarton, the well-known historian of science, the Muslim domination of science (especially astronomy) was so complete for the first 350 years after the founding of Baghdad (762 A.C.), that he assigned each 50-year period of scientific achievement exclusively to a Muslim. Unfortunately, the sacking of Baghdad in 1258 A.C. at the hands of Hulagu Khan marked a major disaster to the development of science, for the world as a whole but especially for the Muslims. In the post decolonization phase after World War II, although Muslim countries began to pay attention to education, science and technology, applied and Islamic astronomy was left out and almost forgotten. Therefore, it is not surprising to see the annual chaos that accompanies the *'Īd* occasions: It is nothing more than a reflection of the scientific situation in the Muslim world.

The process of keeping track of time is almost as old as human civilization. Unsurprisingly, almost all early civilizations started with the lunar calendar—around the Mediterranean, the Babylonians, Greeks, Jews, and Egyptians; in the West, the Aztecs and Incas; and in the East, the Chinese and Hindus. Almost all of them started with the use of the purely lunar system, subsequently transforming it (through intercalation) into a luni-solar system in which the system is basically lunar. In the West it seems that the misuse of power by pontiffs (pre-Christian, Roman authorities) in the matter of intercalation angered Ceasar enough to cause him to shift to a purely solar calendar, thus weakening the lunar system's importance. However, the lunar calendar received a major boost when the Muslims adopted a purely lunar system (632 A.C.)—exact and fixed—of 12 lunar months. Prior to this the Makkans would change the sacred nature of the specific months (in which fighting was prohibited) to suit themselves through intercalation in a way similar to the Roman pontiffs. The Qur'an provides the following two pertinent verses.

> They ask thee concerning the new moons. Say: They are but signs to mark fixed periods of time in (the affairs of) men, and for Pilgrimage . . . (2:189)

> The number of months in the sight of Allah is twelve (in a year) . . . (9:36)

By using the first visibility of the crescent moon to determine the beginning of the new month (a practice observed in earlier times by many other calendar users like the Babylonians, Jews, Incas, Aztecs, etc.), the Islamic lunar calendar was made even more simple and self-contained. But more importantly, with the use of earliest visibility, the lunar calendar—already challenging to the fields of celestial mechanics, spherical astronomy, and mathematics—became scientifically challenging to the fields of observational astronomy and optical physics as well. During the entire Golden Era of Muslim science, working out the calendrical astronomy, including the prediction of visibility, became an intense, religious, and testing activity for the best scientific Muslim minds. However, very little serious attention has been paid to the development of the lunar calendar since the downfall of

Islamic science and the subsequent shift to the solar calendar, especially in the 19th century.

Today, if a calendar is to be globally useful, the dates have to be interrelated between any two places through a date line. Both lunar and solar systems are basically determined locally. Until nearly the end of the 19th century, Europe and the rest of the world determined time and date according to the local meridian of each place. The solar system, indirectly and somewhat accidently, began to be internationalized with the arbitrary adoption of Greenwich (in 1834) as prime meridian to facilitate determination of a ship's position at sea. Eventually, this gave rise to the international solar date line. Gradually, countries adopted the use of the arbitrary solar date line for calendrical use, some in more recent decades. The lack of a lunar date line resulted in the lunar calendar becoming stuck and getting left behind. The need for an international date line for lunar calendars—specifically in the context of the Islamic lunar calendar—came under serious consideration and study by me, and lately has become an operational issue.

Three essential elements underlie a date line and a unified international Islamic lunar calendar; namely, the astronomical prediction method of determing a new moon's visibility, its use on a global scale, and the considerations for its global (practical) application and implementation. A brief account of the recent progress in these areas is presented in the next sections.

ASTRONOMICAL PREDICTION METHOD

As we have noted earlier, a lunar calendar is a calendar of civilizations (see the table at the end of this paper). Almost every civilization has made use of it at one time or another, and many continue to use it today. Beginning a new month with the appearance of a new crescent was a natural thing to do in the ancient times. Even though, the purely lunar system was gradually transformed into a luni-solar system, the practice of using the first visible crescent remained in force with subsequent civilizations and was further strengthened by the Muslims.

Using long-term observational records, a simple astronomical rule (criterion) for prediction of the new moon's earliest visibility was laid down as early as the Babylonian era, and remained in general use during the latter civilizations of the Jews, Chinese, Greeks, Hindus, and Muslims. Around the 4th century A.C., the Hindus begun to treat the problem on mathematical and physical grounds. But it was to the credit of the Muslims (in view of its enormous importance) that after intensive work, purely physics-based prediction methods were evolved and continually improved upon, notably by Yaqub Ibn Tariq, Habash, al Khwarizmi, Moses, al Battani, al Farghani, Thabet, al Sufi, and al Tusi. However, as Islamic science and astronomy declined, the prediction methods which they developed stagnated and then, gradually, were all but forgotten.

Nevertheless, because lunar visibility is of general astronomical interest, a modern attempt at developing a criterion was made at the beginning of this century using a new observational data set, taken from Greece. But this criterion remained obscured until it was brought out into the Islamic world.[1] At the same time, another purely theoretical, physics-based method, a modern improvement to the 11th century Islamic method, was developed by Bruin.[2] These two independent methods were found to be in serious conflict with each other and thus unreliable for use until I was able to identify the error and thus produce a combined, theoretical-observational criterion based on the two independent methods. The criterion has been further improved upon by me at the two extremes and now represents a good starting point, taking into consideration the effects of such variables as:

- the moon's distance from the earth, the crescent's width and light intensity;
- the brightness of the sky near the western horizon at sunset;
- the lunar mountains' shadowing effect;
- the atmospheric refraction effect; and
- the human eye's role as a detector of contrast.

It is very desirable to develop simpler techniques (or criterion) which are relatively easy to use but fairly good as a first degree approximation. With this in mind, Ilyas developed two separate criterion. One of these is based on the moon's age and the other on moonset lag from sunset. The latter is exceptionally simple and accurate up to mid-latitudes. The basic criterion may need slight improvements for specific regions for which elaborate observational work is needed, But, in any case, the principal features of a uniform calendar are expected to remain unchanged.

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1. Mohammad Ilyas, "Sighting of a New Moon." J. Muslim World League (Makkah) 4 no. 11 (September 1977): 38.

2. F. Bruin, "The First Visibility of the Lunar Crescent," Vistas in Astronomy 21 (1977): 331.

GLOBAL VISIBILITY OF THE NEW MOON AND LUNAR DATE LINE

Given a reliable astronomical prediction method (criterion), it is not difficult to make use of it for prior determination of the expected visibility at the evening and the commencement of the new Islamic month for any desired place. Indeed, this was a routine practice in the Islamic world from the 8th century onwards. However, in modern times, one needs to examine the matter globally. To make the necessary computations over the entire earth's surface (for several consecutive days for each new month) requires nothing short of a modern computer. Indeed, without today's developments in computational machines, this kind of work would be practically impossible. And without making such calculations globally, the study of a realistic international calendar, fulfilling religious needs, would not be possible. In fact, even though the necessity and the basic concept of the Islamic lunar date line—the backbone of an international calendar—had been developed,[3] it was only in 1978, when the first set of such charts were issued, that the nature of global visibility and a proper lunar date line became clear. The following years saw a continuous build up, leading to the publication of global data set.[4]

Without going into too many of the technicalities, we can look at the outcome of the global scale computations. The basic issue is to relate the phenomena of "first visibility" at two places A & B, where B is either to the east, west, north, or south of A. The basic questions that arise are:

1. If we expect the visibility at A what happens to it at B?
2. Is there general systematic behavior and continuity or only random behavior?
3. If the moon is sighted at A first, will the moon be sighted at A first again the next month?

To answer the above questions, the underlying computations are rather involved and complex but the outcome is very simple and satisfying. This is illustrated schematically in the figure below. We note that at each latitude circle, there is a critical longitude at which the moon is expected to become visible first because the minimum astronomical conditions are satisfied (at

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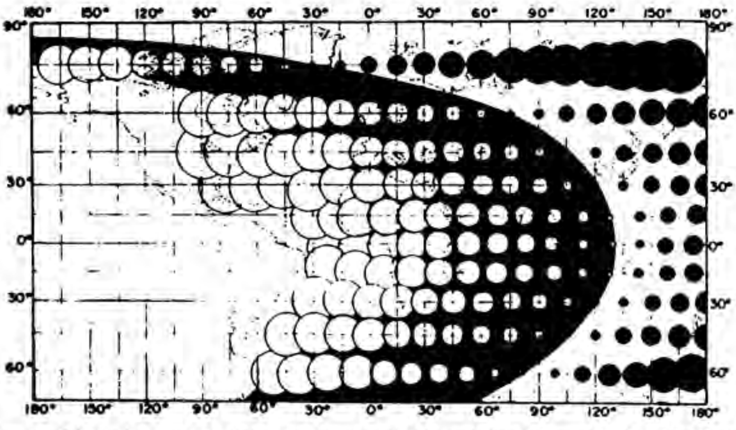
3. Mohammad Ilyas, "Sighting of a New Moon."

4. Mohammad Ilyas, *A Modern Guide to Astronomical Calculations of Islamic Calendar, Times, and Qibla* (Kuala Lampur: Berita, 1984).



the time of local sunset). To the east of this critical longitude, the "chance of visibility" decreases rapidly (growing dark disks) due to earlier arrival of sunset. To the west, the "chance" increases rapidly (growing white disks) due to the delayed occurrence of the local sunset, allowing the moon to appear higher, bigger, and brighter. Thus, the line joining the first visibility longitudes at different latitudes becomes the (Islamic) international lunar date line (ILDL). Due to some uncertainty (an inherent property of an observational event) in the prediction "criterion," there is a corresponding uncertainty zone around the ILDL covering approximately 20° to 30° in longitude on each side. In this zone, we can expect to sight or miss the new moon. To the west of this zone, we definitely expect to sight the moon under clear weather conditions; and to the east of this zone, the moon will be sighted the next evening. This is a new dimension to our understanding of global visibility, calling for serious attention from our religious scholars.

ILDL's Global Application and Implementation

Basically, the ILDL is a natural demarkation line, similar to the arbitrarily fixed (systematized) solar date line, and thus allows the transformation of the local lunar calendar into an international lunar calendar without affecting the basic condition of (expected) "local visibility" at each and every place. In other words, if everyone adhered to the "local condition of expected visibility" in deriving their local calendars, without worrying about anybody else, the end result would be a systematic and unified international Islamic calendar with global continuity. Also, because such a (calculated) calendar would be closest to the actual sighting situation, it would allow adjustments for occasional departures of "acutal sighting" from the calculated dates without seriously affecting the entire calendar. For example, a month calculated to be 29 days may change to 30 and an adjacent one to 29 (mainly in the uncertainty zone only).

The ILDL is not necessarily a vertical straight line. In general, it is a curved line with greatest curvature at higher latitudes. Therefore, certain simplifications may need to be made to the ILDL at higher latitudes. This matter is one of the areas to come under serious scientific and religious consideration in the immediate future. A vertical line approximation, whereby a vertical line drawn at the apex of the calculated ILDL is used for the general international Islamic calendar, has several good justifications, including the ruling for sufficiency of a single (acceptable) observation of sighting for the whole country. A first cycle approximation and similar other matters have been discussed at length elsewhere and need not be repeated here.

An important consideration will be the global observance of important religious events like *'Īd al Fitr* and Hajj, and the question of whether everyone can celebrate these events on the same day, worldwide, without scientific absurdity. In the light of our new understanding of global visibility patterns and the resultant international date line, etc, it is not difficult to see that the date line transforms the local date into an international date. Any event thus begun from the date line would be on the same day globally (i.e., within 24 hours around the global surface). But of course, there is the religious question of actual sighting especially for certain events like *'Īd al Fitr*. It will be for the *ulamā* to examine the underlying issues which have been identified elsewhere.[5]

Regardless of how we decide to determine the specific dates like *'Īd al Fitr* or the first day of *Ramaḍān*, the most important point is that the same criteria be implemented everywhere in the Muslim world. Indeed, today the absurdly differing dates between different Muslim countries and the resultant chaos we experience each year on the occasions of the *'Īds* are due more to variations in calculations and less to the adoption of calculations by some countries and actual sightings by others. Using the practice of actual sighting for one or two important events would tend to give a seriously different date only if the calendar had been calculated wrongly according a criterion other than "expected" visibility. In this case one may be trying to sight the new moon on the 28th day of the month, as is the practice in many countries!

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5. Ibid.

CONCLUDING REMARKS

In the light of the foregoing discussion, it is clear that the issues confronting the development of the Islamic calendar are, to begin with, of a scientific nature, even though some religious considerations need to be addressed. The most urgent matter is that of uniform implementation of a general purpose international Islamic calendar; that is, only the "expected visibility" criterion for the advance calculations of calendrical dates should be used. Side by side, we need to build up the scientific aspects necessary for the perfection of calendrical science and related astronomy. Indeed, having seen it evolve over the last 15 years, I can now say that, as a result of intense efforts at various levels, there is considerable understanding of this need throughout the Muslim world. More importantly, progress is already being made toward coordinating an international effort to develop an international Islamic calendar program. A series of seminars and regional meetings are being held and this very meeting is a link in this chain. A good many institutions are taking a keen interest in the development of this work. These are very positive developments. We just have to continue working toward perfection and communication with patience.

It must be pointed out that the Islamic calendrical system is the simplest of all lunar calendars in use. The implementation of the single calculation/prediction system and subsequent improvements would go a long way to make it a living system of common use. Perhaps it would be suitable to end this paper with a quotation from a note of caution I wrote not long ago:

> In recent years there has been a tendency to arrange for a two- or three-day seminar to come up with solutions there and then. This kind of quick solution approach has, it seems, done more harm than good. The underlying science has been forgotten through centuries of neglect. All kinds of simplifications have been introduced to bypass the required rigors of physics and mathematics, so that now we have to relearn and advance Islamic astronomy all over again. The process has to be slow with constant and continuous effort. Modern scientific methods are such that what we work out today is open for review and refinement tomorrow. Our approach will have to be to find an acceptable interim short-range solution to a problem, if possible, while working on a more perfect long-term solution.

Table Summary of Development of Astronomical Criterion: B.C.–1986

Period	Astronomers	Criterion	Remarks
–B.C.	Ancient (babylonians)	$a_S \geq 12°$ (or moonset 48 min. after sunset)	based on observation
–B.C.	Chinese Greeks (Aratos. Berossos of Chaldeon [300 B.C.], Ptolemy)		using Babylonian rule, not much attention to this area
–500 A.C.	Hindus (Surya Sidhanta & Panch Sidhantika)	$a_S \geq 12°$	perhaps based on Ancients' observations (elaborate system of calculations developed and importance of lunar width realized).
767–778	Ya 'qub ibn Tariq		tables for calculation
740–840	Habash		calculation system developed
–830	Al Khwarazmi	$9.5° < a_L$	—
831–861	Moses ibn Maimon (Maimonides)	$9° < a_L < 24°$ $a_D + e > 22°$	general
850–929	Al-Battani Al-Farghani	$a_S < 12°$ (when a_L is large)	Autumn and Spring (calculation system developed)
826–901	Thabit b. Qurra	$11° \leq a_L \leq 25°$	—
–986	'Abd al Rahman al Sufi	$a_S \geq 12°$	(follows Babylonian rule)
973–1048	Al Biruni		refers to Habash and Battani
1258–1274	Nasir al Din al Tusi		—
15th Century	Ghiyath al Din al Kashani	$a_S \geq 12°$	as Babylonian; begin sighting 24 mins. past sunset
1910-1911	Fotheringhim & Maunder	$a_D (\Delta Z) \geq f(Z, A_Z)$	(or $a_S > 11°–12°$ for ΔA_Z –0: observational)
1977	Bruin	$a_S(\Delta Z) \geq f(Z_{ms} W)$	theoretical, incomplete and erroneous
1981–1984	Ilyas	$a_D(\Delta Z) \geq f(a_L, \Delta Z)$	composite of two independent criteria
1983	Ilyas	Age ≥ f(lat., season, yr.)	simpler approximate criterion
1981-1994	Ilyas	$a_S \geq$ f(lat., season) (moonset lag [min.]): 41 ± 2 at 0°, 46 ± 4 at 30°; 49 ± 9 at 40°; 55 ± 15 at 50°	more accurate, shows quality of Ancients more general rule for upto mid-latitudes

Definition of symbols for positional parameters

L=Longitude of geographical location
ϕ=Latitude of geographical location
λ=Longitude (Ecliptic) of a heavenly body
β=Latitude (Ecliptic) of a heavenly body
α=Right ascension (equatorial) of a heavenly body
δ=Declination (equatorial) of a heavenly body
A_Z=Azimuth (bearing on the local horizon circle w.r.t. geographical north) of a heavenly body
A=Altitude (from local zenith) of a heavenly body
Z=Zenith ($Z = 90° - A$) angle of a heavenly body
a_D=Arc of descent between two heavenly bodies, local ($a_D = Z_1 - Z_2 = A_1 - A_2$)
a_S=Arc of separation between two heavenly bodies.
e=Elongation between two heavenly bodies (i.e., direct angular separation of angle subtended at earth) Bruin (1977) has defined e as longitudinal separation (i.e., $\lambda_1 - \lambda_2$) and must not be confused with the general definition as above.
a_L=Arc of light (same as e in sun-moon system)
w=Width of the lunar crescent ($w = d \sin^2(a_L/2)$)
d=Lunar diameter

Lunar Islamic Calendar: Issues and Answers

Omar Afzal

Abstract

The indeterminacy of the first date of an Islamic month creates a nightmare for the *'ulama* and community leaders who are often expected to make a correct judgment on the basis of, at best, hard to verify claims of local moon-sightings or sightings from distant locations. This paper examines the three most critical areas in any discussion of a global Islamic calendar. The first part discusses the inadequacies of various fiqh positions on crucial issues such as the *ikhtilāf maṭāli'*, *khabar*, *shahādah*, etc, and urges the *'ulama* to re-examine their views on these issues in the light of the progress of human knowledge if they expect to improve upon the present chaotic situation. The second part defines the basic issues involved in a purely lunar calendar. It explores in depth the problems involved in switching from the first visible crescent to the conjunction or the observable-calculated or assumed-to-have-become-visible crescent as the criteria for determining the start of a lunar Islamic month. The third part critically evaluates various recent positions taken on these issues, especially the recommendations of the Kuwait (1973) and Istanbul (l978) conferences, as well as the Makkah (1986) and Cairo (1986) meetings. A general consensus about the first date of an Islamic lunar month will develop only if the proposed criterion is not in an apparent contradiction with the Qur'an and the Traditions, conforms to the basic astronomical data, and is reasonably accurate in predicting the beginning of the lunar month.

Introduction

The day of the Islamic month which is the basic unit of every calendar begins at sunset when the solar disk completely disappears below the horizon, and ends at sunset next day.[1] The beginning and the duration of an Islamic month, as defined and practiced since the earliest Muslim community in Madinah, depends on the earliest visible waxing crescent and the time which elapses from one crescent to the next.[2] It may be 29 or 30 days,[3] but not necessarily in any fixed order such as alternately, as several calendar makers have assumed.[4]

The synodic month—the average time between successive lunar conjunctions—as derived from the mean orbital elements, is variable from occasion to occasion (from 29.26 days to 29.80 days) with a mean in the long run of about 29.53058818 days. For 1987, it was 29 days 12 hours 44 minutes and 2.9 seconds (Astronomical Almanac, 1987:D.2). Hence, an Islamic calendar based on a visible lunar crescent (from the surface of the earth), like any lunar calendar, has to grapple with several major problems, especially the following:

1. A visibility curve[5] (extending westward in a parabolic shape).
2. Limits on the visibility[6] in higher (40°–80°) latitudes.

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1. On this point there is a consensus though the Shi'ahs differ slightly about the exact time of the sunset.

2. Bukhari: "Don't fast unless you see the crescent (of Ramadan), and don't give up fasting until you see it (the Shawwal crescent)." (3:130 in Khan 1976)

3. "The month is like this (ten fingers times three), and also like this (ten times two plus nine fingers)." Bukhari. (3:132 in Khan 1976)

4. V. V. Tsybulsky, *Calendar of Middle East Countries* (Moscow: Nauka, 1979); V. Illingworth, *Facts on File Dictionary of Astronomy* (New York: Facts on File Publication, 1985); and W. M. O'Neil, *Time and the Calendars* (Sydney: Sydney University Press, 1975).

5. S. K. Abdali, "On the Crescent's Visibility," *Al-Ittihad* 16, no. 1 & 2 (1979). He discusses some of the difficulties associated with the lunar visibility curve. The proposed international lunar date line will run north-south at X—the easternmost point of first visibility, instead of the actual parabolic curve. Except some minor adjustments to accommodate the political boundaries the LDL may not be moved eastward, as it will amount to declaring Islamic occasions in those areas a day ahead where the crescent's visibility was not possible that evening.

6. Ibid. Figures 1 and 2 both attest that the first visibility beyond 60° N/S latitudes may not occur several days after the conjunction thereby making many months 30, 31, and even 32 days.

3. An ever shifting lunar date line,[7] resulting in every lunar month being of 29 and 30 days simultaneously[8] (though in different geographical regions).
4. Indeterminacy.[9]

From time immemorial, calculations based on observations have been made to predict the first visibility of the crescent. The Babylonians, the Jews, the Hindus, and later the Muslim astronomers (al-Khwarizmi, al-Baṭṭani, al-Biruni, etc.) have suggested various criteria. Recently, the efforts of Abdali (1979), Minai (1980), Ilyas (1984), and others have brought into focus the issues related to the crescent's first visibility, and how modern astronomy (not to be confused with astrology—the prediction of future events) helps us solve some of the complications associated with a global Islamic calendar. Abdali (1979) used al-Biruni's criterion and Danjon's (1932)[10] limits on crescent visibility and calculated[11] the moon's position for the day/date of the conjunction and the day following it to predict the chances of the first visibility in various regions (see the table Data for Crescent Information following the this article) of the

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7. If we compare the VCs of Sha'ban, Ramadan and Shawwal 1399 in Figures 1 and 2 we notice that: 1) the first visibility of Sha'ban's moon started somewhere in the Arabian Sea; 2) Ramadan in the Pacific; and 3) Shawwal in the Atlantic. Also see M. Ilyas, "Calendar Calculation System," *Rabitah Journal* May (1981) and M. Ilyas, *Islamic Calendar, Time and Qibla* (Kuala Lumpur: Berita Pub. Bhd, 1984).

8. The area between the Arabian Sea and the Pacific Ocean had 30 days of Sha'ban; the area between the Pacific and Atlantic Oceans had 30 days of Ramadan in 1979 (1399). On the other hand, the area before the Arabian Sea had 29 days of Sha'ban, and the area between the Atlantic and the Pacific Oceans had 29 days of Ramadan. The VCs of each month attest to this basic fact of the lunar Islamic months.

9. Abdali, "On the Crescent's Visibility" and S. K. Abdali, "Notes on the Data for Crescent Observation" (unpublished, 1985). H. A. Minai, "Sightability of the New Moon," *Islamic Order* 1, no. 1 (1980); Omar Afzal, "Witness or Calculation," *Tahrik* 4, no. 1 (1982), Ilyas (1984).

10. Abdali, "Notes on the Data for Crescent Observation."

11. Committee for Crescent Observation (CFCO) data for 1973–1989. Also see LeRoy E. Doggett and P. K. Seidelmann, "Calculation and Observing the Crescent Moon," (unpublished, 1987); and B. D. Yallop, "First Sighting of the New Moon in 1987," RGO Ast. Inf. Sheet (1987) and , B. D. Yallop, "First Sighting of the New Moon in 1988," RGO Ast. Inf. Sheet (1988) and others for calculations.

globe. The data collected since 1979[12] strongly indicates that the observability of the crescent may easily be predicted in all cases fairly accurately with the exception of a very few months when the variables are very close to the minimum limits on visibility.[13] By testing it against more verifiable observational data, obtained over a period of time, Abdali's computations may further be improved for accuracy.

Ikhtilāf Maṭāli/Khabar/Shahādah

The issues of the longitudinal-latitudinal variations at sunset, the testimony of the witnesses, and communication of the news of the first visibility have remained the focal points[14] in any discussion of the topic

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12. The Committee for Crescent Observation based in Ithaca, New York (USA) with more than 45 affiliated committees over North and South America, Europe, and Asia has been collecting this data since 1979. It also verified the data against the claims of sightings and official/local announcements, declarations of *'Idayn*, Ramadan, etc., in various countries since 1972.

13. The crescents for the months of Ramadan 1407 (1987) and Safar 1408 were good examples. According to both Abdali and Doggett, the Ramadan crescent could not be seen from Brunei to Morocco before the evening of April 29, 1987. However, in all the 48 contiguous United States the chances of its visibility on April 28 were fairly high. Confirmed reports of sightings were received only from Washington D.C., southwestern states and the west coast. On a clear and cloudless horizon, despite diligent search until after the moonset time, a large number of observers in southeastern and central states were unable to see any trace of the crescent. Why was it not visible from Georgia to Tennessee, Texas, and New Mexico where atmospheric conditions were also favorable and the calculations showed good chances of its visibility? The answer may be the horizontal distance of the moon from the sun which was only 0°–2° and its age (22–25 hours) at the sunset in those areas. Though many limits on the crescent's visibility were met, these two factors made the difference. For Safar 1408, a 42- to 44-hour old moon could not be seen on September 24, 1987 in eastern and midwestern states.

14. The Kuwait, Istanbul, Makkah and Cairo conferences, M. Kahf, "Determination of Islamic Occasions and the Islamic Calendar," *Al-Ittihad* 17, no 2 (1980), Shahabuddin, "Determination of Islamic Month and Occasions," *Tahrik* 3, no. 2 (1982); Afzal, "Witnesses or Calculation"; Ali R. Abuzaakouk, "Legal Decisions about the Sighting of the New Moon of Ramadan" (unpublished). The books of traditions and their commentaries, fiqh books and innumerable tracts and articles appearing on this and related issues supporting or refuting one line of argument testify to the keen interest. Unfortunately, the tech-

among the Muslim scholars. These three important issues can easily be resolved if the *'ulama* and Muslim community leaders keep the following in mind:

1. A crescent cannot be sighted before the instant of conjunction.
2. Because of the spherical shape of the earth, a crescent, like the sun, is not visible everywhere at the same instant. It takes 24 hours for the earth to rotate. Therefore, it takes the same time for the crescent to become visible over the globe (within 0°–40° north/south[15]), as the following figure shows:

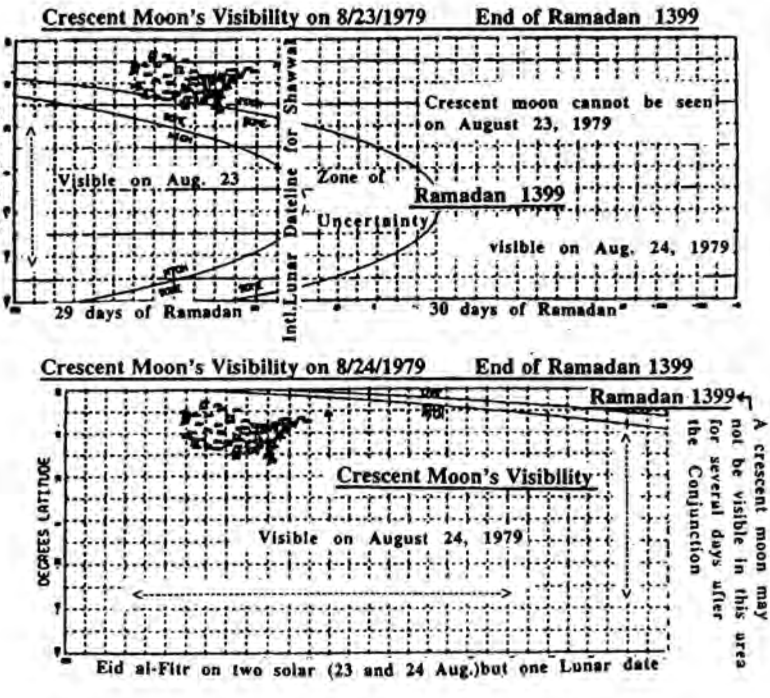

Figure 1.

nical aspects of the crescent's visibility are pushed aside in favor of trivial though popular issues such as the number of witnesses, communication of the news of visibility. The *'ulama* in the U.K. and Europe, as late as August 1987, were insisting that eyewitnesses who claimed to have seen a crescent when the moon was only 4.8 hours old on May 27, 1987 are "correct" and the large number (9+3=12 from two places) proves that all observatories and their calculations are *wrong*.

15. The earliest visibility for various months in 1988 varies from as far north as just east of Japan to as far south as just north of New Zealand.

3. A lunar day/date will rarely coincide/overlap with the solar day/date. The first lunar visibility will seldom, if ever, occur at the International (solar) date line.[16] Moreover, the solar day begins at midnight whereas the lunar Islamic day begins at sunset.
4. A lunar day/date will generally extend over two solar days/dates, though never to more than two,[17] as Figure 1 shows.
5. Under normal atmospheric conditions, when the crescent first becomes visible after the sunset[18] at location X on the globe, all locations within a certain parabolic curve west, northwest, and southwest of X will see the crescent. The whole world from the west of X to the east of X will see it within the next 24 hours (a single lunar day/date spanning two solar day/dates).
6. Places in the region east of point X outside the visibility separator curve will not see a crescent until the next day. In other words, the first visibility cannot extend eastwards beyond the initial point X.
7. A crescent is always visible on the 30th. day.[19]

The assertions made above considerably change our understanding of the problems associated with the beginning of an Islamic month, especially the *ikhtilāf maṭāli'* (horizons, in the sense that there are multiple points from which to observe the horizon), *khabar* (news), and *shahādah* (eyewitness accounts).

16. Figure 1 shows that the first visibility of Ramadan 1399 began on August 23, 1979 in the Atlantic, and not at the International Date line. The visibility extended to areas west-N/S west of the initial point at their sunset time until the whole world between 0° and 60° N/S latitude saw the crescent within 24 hours (a lunar day out of two solar dates) by August 24.

17. The first visibility cannot extend eastward from the initial point on August 23, 1979.

18. Figure 2 shows the parabolic shape of the visibility separator curve for Sha'ban, Ramadan, and Shawwal 1979 (1399).

19. RGO Astronomical Information Sheet #6, Danjon (*L'Astronomie*, Feb. 1932), Flammarion Book of Astronomy (English Trans. 1964), and other books on the astronomy of the moon. The Muslim *'ulama* should note the drastic implications: if a crescent is not visible on the 30th day then the beginning of the month was wrong, even if attested by hundreds of witnesses from several places. Ibn Abbas asked Kuraib to fast on the 31st day of Ramadan when the crescent was not seen in Madinah (though it was his 30th day, according to his own sighting in Syria) but only the 29th day according to the sighting in Madinah. Nowadays Muslims celebrate the *'Id* on the 31st day, irrespective of whether the crescent becomes visible or not.

First, the whole world is certainly not one *maṭla'* (horizon) at the instant the crescent is first sighted at point X. It becomes one *matla'* in a 24 hour period. (See Figures 1 and 2.)

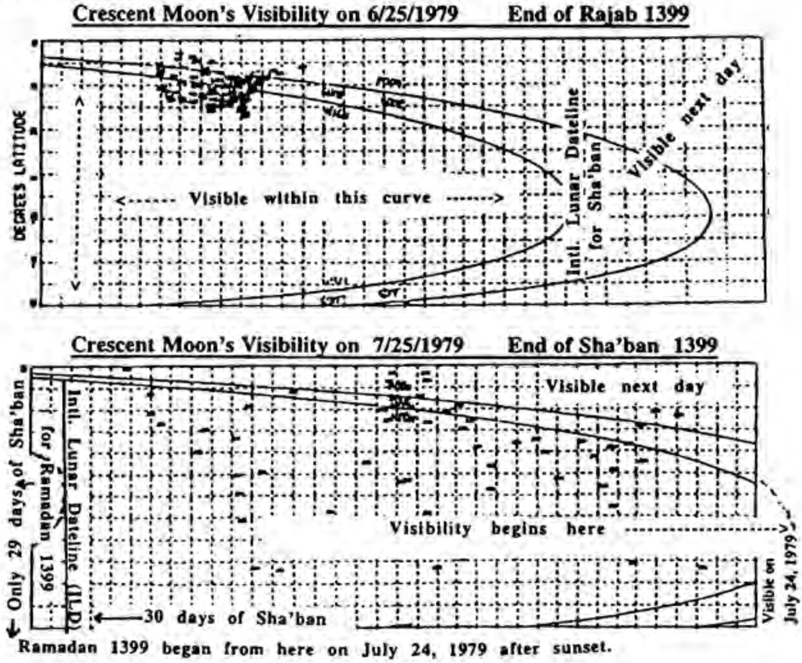

Figure 2.

Second, a new Islamic (30th) day of the month has already begun for the places east of the initial sighting (point X) as the sun and the moon have already set there. They will see the crescent only the next day, but not before.

Third, if the crescent is not sighted in locations west, northwest, and southwest of X (the eastern-most point of initial sighting) then the claims of sighting at X must be carefully evaluated and generally disregarded if the calculations also strongly point against it.

Fourth, if the new crescent is not visible at X on the 30th day then the testimony regarding the beginning of the month must be false.[20]

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20. The *'ulama* in Saudi Arabia, Kuwait, Egypt, etc., and the ISNA Fiqh Committee in the USA insist on celebrating *'Id* on the 31st day, even if the moon is not sighted on the 30th day. The hajj in 1987 and many other occasions were declared because of a misinterpretation of the 29/30-day hadith. An Islamic

• IKHTILĀF MAṬĀLI'

If we declare the beginning of an Islamic month for the whole world the instant a crescent is sighted at X, assuming the whole world to be one *maṭla'* (horizon) then we run into several problems. In some areas the sun has yet to set. What day/date will be assigned for the remainder of the day (until sunset) for those areas? In some regions it is high-noon, in others it is sunrise, and still in some others it is midnight. How will the day and date be determined for all these areas? If we extend the day/date to the next sunset, then what is the gain?

Accepting the physical reality of *ikhtilāf maṭāli'* means determining the Islamic date from the local sunset time, which is the only way to determine the beginning of an Islamic day/date. It does not mean chaos or celebrating Islamic occasions on 3 or 4 different days, as we often encounter now. It means unifying the whole Muslim *ummah*, all over the globe, on a single lunar day/date, which starts at the sunset time from the easternmost point of visibility moving westward until the rest of the world sights the crescent over the next 24 hours, the length of a day on the earth.

• LUNAR DATE LINE

Ikhtilāf maṭāli' is intertwined with the issue of a lunar date line. Every calendar needs a date line. The question is how to define the lunar date line (LDL)?

A lunar date line differs from the universally accepted solar date line (international date line or IDL) in several ways. IDL is longitudinal. It runs north-south along the 180° longitude with some minor adjustments. IDL is fixed for all months of the year, and for all years. The new day begins at IDL at 12.00 mid-night. There is always a difference of one day at 180° West and 180° East, although the two are on the same longitudinal line. Two islands straddled only 100 yards apart at IDL will have two dates, the one west of 180°E having a weekday one day ahead of the one east of 180°W.

A lunar date line (LDL), if the criterion is moon's visibility, is of the shape of a parabolic curve. It extends along the visibility curve (VC) west/north-south west, and has the latitude through X as the axis of sym-

month cannot be more than 30 days only if the month was started on a correct date. For more details see the Committee for Crescent Observation (see footnote 12). The majority of the Muslim jurists have shown a consensus on this issue. For details see Tirmidhi (*Bab al-Saum. . .*), *Al-Fiqh 'Ala Madhāhib al-'Arba'*, Vol. 1, Afzal's letter to ISNA FC (1982–1986), etc.

metry. LDL is not fixed; it changes every month. The Islamic lunar date line begins at the sunset along the VC. Areas inside the curve will have a date ahead of those which are outside it. The instant of a new lunar date is not the same time of the clock everywhere on the globe.

If we define the LDL as a longitudinal north-south line through X, instead of the visibility curve, to eliminate some of the problems mentioned above, we may start a new date at a fixed-clock time all over the globe. However, it will not solve the rest of the problems. We will include regions of nonvisibility into a lunar date line. The regions of the earth north of latitude 50°N and south of 50°S may not sight a new crescent after 30 days of the previous month. As the sunset time changes constantly the LDL will have to change with it. Besides, LDL shifts continually every month.

• SHAHADAH

An eyewitness is accepted only when the possibility of an event to occur is physically present. When the possibility does not exist or cannot be verified independently then the most reliable witness account cannot be acceptable and must be rejected. The Qur'an and the Sunnah do not ask the Muslims to believe witnesses when they are verifying an event which is nonexistent or physically impossible. The Qur'an counts some guessing as a sinful act, and the Messenger Muhammad advised us to be an eyewitness only when the event was visible to us as clearly as the sun is visible to all. But if the claims of moon sightings by the Muslim eye-witnesses and their unconditional acceptance by the *'ulama*/jurists and Muslim community leaders in Muslim lands and decision-making bodies[21] during the last three years (1985-1987) are any indication then the Muslims have seen the impossible. They have seen a waxing crescent 1–2 days before the new moon phase,[22] 0 to 10 hours after the conjunction,[23]

21. CFCO's meticulously kept "International Rumor Register" shows beyond any doubt that the Muslims in all parts of the world claim crescent sightings ranging from absurdly impossible to strongly suspicious. In compiling this register CFCO recognized reporting, investigating, and diagnosing of all reports or rumors of suspected cases of crescent sighting are essential to maintain the confidence in the compiled data of observations. These reports were collected from orally conveyed information, news reports, official declarations, astronomical journals, etc.

22. Saudi Arabia, Shawwal 1986, in the USA ISNA 1987, etc.

23. Middle East, especially Saudi Arabia, 1972–1987. ISNA FC 1979–1987.

when the moon was setting before or 0–10 minutes after the sun,[24] after the moonset time,[25] half a day to 2–30 minutes before the sunset,[26] during or before a solar eclipse in their area,[27] 30°–45° degree above the horizon,[28] in almost all directions other than where it might be, and these "miraculous" sightings may continue in the future. Often the *'ulama* who as judges, muftis, imams, etc., decided the beginning of a new Islamic month based on these witnesses. They supported these blatantly false claims of moon-sighting by misplaced arguments such as the following: the Messenger accepted eyewitnesses without question,[29] he has instructed the Muslims against accepting calculations,[30] one of the accepted *madhhabs* (Muslim school of jurisprudence) permits the testimony of a single

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24. In Pakistan on Monday April 27, 1987. Also ISNA FC 1987.

25. In Peshawar, Pakistan, a person claimed on Tuesday, April 28, 1987 that he saw the crescent around 7:30 p.m. The moonset in that area on that day/date was between 7.01 and 7.08 p.m. In Chicago a person claimed to have seen the crescent on Monday evening as well. In India the Imam of Shahi Masjid Delhi claimed to have seen the Shawwal crescent on May 27, 1987. For details see CFCO's Intl. Rumor Register 1979–1987.

26. Two families (of 7 adults and some children) in New York City claimed to have seen the crescent of *'Id* 24 minutes *before* sunset. From Saudi Arabia, Egypt, Pakistan, Yemen, etc., such claims are very common.

27. See Shaikh Tantawi (July 7, 1983), *al-Yamama* (Ramadan 30, 1407), *al-Ahram* 1982–1984, etc., for the crescent-sighting claims *before* or at the solar eclipse, and also Shaikh Baaz' reply in *Al-Mujtama'* (June 1987). Egypt's Ministry of Awqaf announced that March 29, 1987 was the last day of Rajab, and that Sha'ban will begin on March 30. Egypt witnessed a total solar eclipse on March 29, 1987 (*Astro. Almanac* 1987, p. A80 for other details). How the crescent was visible in Egypt on March 29 during a total solar eclipse is a mystery which only its Awqaf Ministry can explain. *Al-Ahram* published the Ministry's announcement and the photographs of the eclipse on the front page the same day.

28. In 1986 in Westchester county, N.Y., one out of a group of three claimed to have seen the Shawwal crescent almost 45° to 50° above the horizon. The other two found no trace of it. In Chicago a witness claimed to have seen a crescent in northeastern direction, instead of where the sun was setting. For Shawwal 1987, the lone witness in Madison (the other two with him failed) claimed to have seen the crescent (of a less than 10-hour old moon) south of the setting sun, 2 to 3 minutes after sunset. The moon had already shifted to the north of the setting sun, and a 29-day old moon's new crescent is hardly visible in the first 3 minutes after the sunset.

29. See, e.g., Abu Dawud, no. 2334.

30. See, e.g., Bukhari, 3:137.

witness,[31] the eyewitnesses are very trustworthy,[32] several witnesses have confirmed the sighting,[33] "how could so many of them be wrong," and the sightings have been reported from several locations/countries,[34] etc. When the moon is not visible on the 30th day, even then, the next day is declared the first day of the next lunar Islamic month because of a wrong interpretation of a tradition,[35] which according to them requires it.

As long as the *'ulama* hide behind these and similar excuses they will persist in their ignorant decisions and keep the Muslims confused and in disarray. The much cherished goal of uniting the whole Muslim world on one solar day[36] is fragmenting the Muslims into two or more hostile

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31. For *'Id* 1987 (May) ISNA FC, MCC Chicago, and several other Muslim communities accepted the single witness of Madison, Wisconsin as sufficient to end Ramadan a day early against all odds, and despite a near consensus of the Muslim jurists that for *'Id* at least two *'adil* witnesses are required. Only Thauri, and in one version Shafi'i permit the testimony of one. Those who had to deal with the problem of false witnesses and mistaken objects required the testimony of such a large group of witnesses from all corners of a town or each mosque in the locality that the *qaḍi* had no doubt left in his mind that the month of Ramadan has really ended. Imam Muhammad and Imam Abu Yusuf (the chief *qaḍi* of the Abbasides, living in Baghdad) required 50 witnesses from every mosque. Imam Abu Ayyub raised the number to 150 witnesses, looking to the prevailing conditions. Imam Malik and Imam Abu Hanifa require a very large number of witnesses on a clear sky.

32. Personal communication with several ISNA FC members during 1979–1987.

33. Saudi Arabia's announcements from 1982 to 1987, Egypt's from 1985 to 1987, etc.

34. Saudi Arabia and ISNA FC members for several years in the recent past.

35. For example, see Saudi Arabia's announcement for the hajj of 1987.

36. Since the Kuwait conference (1973) almost all meetings of the Calendar Commission have concentrated their energies on "Unifying the Muslims" all over the world on a single *solar* day/date. In their rivalry and obsession to "lead the Muslims," Middle Eastern countries have created an enormous confusion. Year after year, they have declared Ramadan and the *'Idayn* a day or two ahead of others. Those who insisted on following the crescent had to wait at least one and sometimes two days for it to become visible (Tunis 1985). At present most of the Muslim communities including those in Europe and North America are praying *'Id* on 2 to 3 different days. (For details see CFCO's announcements 1982–1987). At least in Pakistan, the fall of the Ayub government in 1964 and a constitutional crisis in Malaysia in 1983 can be attributed to the crescent's observability.

groups who often celebrate *'Idayn* on 3 and sometimes on 4 different days. The *'ulama* must take into consideration that:

1. The New Moon phase can very accurately be calculated to the fraction of a second for the next several hundreds of years.
2. Danjon's limit (of 7°) is well supported by observational data collected over a period of time.
3. Even under ideal atmospheric conditions a moon less than 20 hours old is rarely visible (less than a dozen sightings in more than a century[37] are documented). Generally a moon becomes visible between 22 to 32 hours of age. Sometimes even a 35- to 40-hour old moon is not visible as was documented for Muharram and Safar 1408 (August and September 1987).

Together with the other factors mentioned earlier (under the heading *Ikhtilāf al Maṭāli'*) the following broad guidelines may be globally adopted:

1. Claims of moon-sightings: (a) BEFORE the conjunction or 0–10 hours after the new moon phase should be rejected immediately; and (b) 11–18 hours after the new moon phase should also be rejected except if made by professional astronomers, from observatories when the minimum limits on its observability have been met.
2. Claims of sighting an 19- to 22-hour old moon should be carefully evaluated. They may be acceptable only if (a) the minimum visibility limits are met; (b) telescopes or at least binoculars are used to confirm the crescent; (c) the evidence is overwhelming; and (d) supported by visibility in areas west/north-south west of the initial sighting.
3. Claims of sighting a 23- to 32-hour old moon may be acceptable when the minimum visibility limits are met.

· Khabar

When the atmospheric conditions hinder the visibility in areas within the parabolic curve west of LDL, the news of confirmed moon-sighting(s) within the VC will be used to declare the first day of a lunar Islamic month.[38] By transmitting the information of sighting the visibility cannot be extended eastward beyond the easternmost points of VC/LDL.[39]

37. *Sky & Telescope*, August 1971, and February 1972; J. Ashbrook, *Astronomical Scrapbook* (Cambridge, Mass: Sky Pub. Corp., 1984).

38. Ilyas, *Islamic Calendar, Time and Ibla*. Abdali, "On the Crescent's Visibility."

39. See Figures 1 and 2 for details.

Declaring Ramadan and *'Idayn*, etc. on the news or information in locations east of the initial point of sighting is tantamount to extending the crescent's visibility to locations where its visibility was physically impossible, and starting a lunar/Islamic day/date in those areas a day earlier.

Communicating the news of sighting to areas west of the initial sighting is redundant as a crescent will be seen there anyway at sunset if the atmospheric conditions do not block its visibility. If a crescent is not sighted there under normal atmospheric conditions then the claims of sighting at point X east of it become questionable.

First Visibility

The position of the moon vis-a-vis the sun and the earth can precisely be calculated for the next hundreds of years, and for this reason the new moon date and time is reported in newspapers, almanacs, calendars, etc. ahead of time. The easternmost first visibility of a crescent—the starting point of an LDL—is not predictable with the same precision for several reasons. Atmospheric conditions limit the sighting. Nearly four-fifths of the earth is water and therefore, may not have an observer at the point of first visibility.

• Conjunction or Visible Crescent

A lunar calendar based on the moon's visibility poses certain difficulties. Places in close proximity may have different lunar day/date (and month) as the visibility of the crescent is limited to within a parabolic curve (VC). The famous hadith of Kuraib according to which the Ramadan (and Shawwal) crescents were sighted in Madinah a day later than in Syria, provides a good example. Often the VC will divide a country into two different date regions. The present cry for a unity of Muslim occasions has highlighted this dilemma, especially after the Kuwait (1973), Istanbul (1978), and Makkah (1986) conferences, which emphasized the unity without addressing the real issues. Another problem is posed by the shifting lunar date line (LDL), as a consequence of which every month is 29 and 30 days simultaneously though not at the same place.

The data collected during the past ten years or so, however, indicate that the first visibility of a waxing crescent may be predicted fairly accurately in almost 11 out of 12 months a year and for all parts of the globe. The situation becomes critical in a very narrow band in which accurately pinpointing the first visibility at present appears to be difficult. A combination of factors—the location of the observer, the moon's age (20–27 hours), its angle (8°–10°), the azimuthal separation or when the moon follows the path of the sun very closely, etc.—cause the uncertainty. Because of the accuracy of determining its beginning, some Muslim astronomers advocate making the new moon phase[40] the starting point of the Islamic month. Switching over from the crescent to the conjunction (new moon) as the criterion for the beginning[41] of the Islamic month is filled with its own perils. We may be able to determine the beginning of the month precisely, but will certainly complicate the definition of the (Islamic) day/date.[42] The conjunction may occur at any time of day or night. Thus we would be forced to make many more involved adjustments than would be required when using the visible crescent as the beginning of the month, however indeterminate it may be at present.[43]

• Airborne/Space-bound Visibility (ASV)

A suggestion has been made to accept the ASV as a valid criterion for beginning an Islamic month. Before making such a suggestion the proponents must try to answer the following questions:

1. How far the guidelines in the Qur'an and the Sunnah may be stretched to accommodate airborne/space-bound visibility of the crescent?
2. Will there be any limits of space and time on the ASV? If yes, then how arbitrary would they be and how will they be fixed?
3. How will the ASV be coordinated with the space and time on earth?

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40. A. Namr, *Bain al-Sunnah wa al-Ijtihād* (Cairo: Dar al-Kutub al-Islāmiyah, 1986), and *Majma'ul Buhuth* (1966). In Egypt, *'ulama* were forced to accept the conjunction as the beginning of an Islamic month under Nasser's pressure in 1965–1966. Surprisingly, some astronomers in Egypt claim that a crescent is *visible* at the conjunction (*Al-Muslimoon*, London First issue).

41. Abdali, "On the Crescent's Visibility."

42. *Astronomical Almanac* 1973–1987, etc. In 1987, Egypt declared Ramadan on Wednesday, April 29, because the crescent will become visible the next morning.

43. Namr, *Bain al-Sunnah wa al-Ijtihād*. If the conjunction occurs 1 minute after the sunset in the westernmost part of a country, but 0 to 10 minutes before the sunset in the rest of it, or 1 minute *after* the *suhur* then what should be done?

If the purpose is to observe the moon from the earth at the conjunction, then we can achieve it simply by scanning the moon through an infrared camera. However, one will not find a crescent there. Instead the moon appears to be semi-full at conjunction as we see in Figure 3 below.[44]

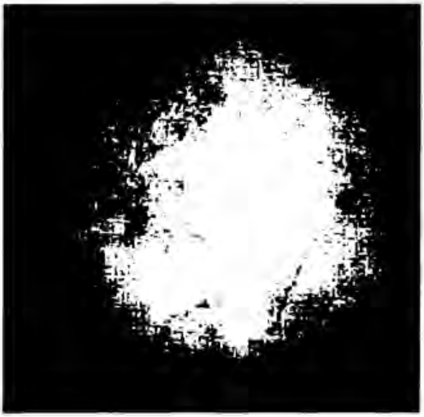

Figure 3.
A synthesis of infrared scans of the Moon (through a passband between 10 and 12 μ in wavelength), showing a view of the lunar face in the light of its thermal radiation (after Shorthill and Saari). Note a conspicuous darkening to the limb of the lunar disk (completely absent on photographs taken through the optical atmospheric window in the scattered light of the Moon).

All forms of ASV have to be excluded from any consideration of the lunar Islamic calendar for several reasons. In the Qur'an, the Sunnah, and the language, the word "*hilal*" is limited to the the "first visible lunar crescent observed from the surface of the earth." Phrases in the Qur'an which mention the phases of the moon, hadith in which the Messenger instructs us to watch for and complete the duration of the month to 30 days, and the words *ru'ya* and *shahādah*, etc., become senseless if ASV is taken to be a valid criterion.[45] For a space observation, the observer's

44. Z. Kopal, *An Introduction to the Study of the Moon* (1971), p. 338.

45. Kahf in "Determination of Islamic Occasions and the Islamic Occasions and the Islamic Calendar" argues in support of changing the definition of *ru'ya, shahadah*, etc., and on relying heavily on the "news." For arguments against Kahf see Maududi, Mufti Shafi', and others beside Afzal in "Witnesses or Calculation," and Shahabuddin in "Dtermination of Islamic Month and Occasions." Several *'ulama* have tried to write the "final" word on moon sighting, often without any knowledge of the geophysical facts or natural laws which govern the moon's visibility. The key concepts for them are: *shahādah, khabar* and *ikhtilāf maṭāli'*. *Ikhtilāf maṭāli'*, as it is interpreted by most of the *'ulama*, including the Ankara-based Islamic Calendar Commission, ISNA, Kuwait, Istanbul, Makkah, Cairo and other conferences, is neither the chaos of "For each town, its own sighting," as many influential groups, including all the *muhad-*

position replaces the earth in the measurement of the elongation[46] of the moon. The angular distance depends upon the position of the observer in space and time. For any space-bound observer, whether a human or a camera, the position will constantly change, and may be changed at will. The elongation for such an observer may extend from 0° to 180° and hence the moon's phases may change from the new moon to full moon and again to the new moon (and within a very short span of time), depending on where and when the observation is made. By adjusting his position (and the distance) in space, an observer may see a crescent at any time of day or night, and at any lunar phase as defined from the surface of the earth. If the limits on space and time are defined in terms of the conjunction and within 200 km from the surface of the earth (and all this

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dithīn, schools of fiqh, etc., have argued; nor "The changes in sunset must be totally disregarded."

The first group assumes a fragmented world with no links to hold them together, and the latter group assumes that the earth is flat. This group claims that once the crescent becomes visible at point X on the earth, it becomes binding on all Muslims living anywhere on the globe. Often other variations of the "instant binding" theory such as "All areas which share the same night" are given as a quick solution, without pausing to have a look to the globe. They are unable to realize that all points on earth share the same night, and all places on earth are east or west of each other. A cursory look at the globe and very elementary knowledge of the moon's motion will convince them that their "instant binding" *fatwā* is meaningless. The whole earth sights a crescent in a 24-hour period. The areas where its visibility is problematic may follow the International Lunar Date Line or any other suitable suggestion. The only other major problem for a global Islamic calendar is all months being of 29 and 30 days simultaneously. The Muslims may adopt the solar calendar for their day to day and international dealings, and use the lunar Islamic calendar for their Islamic occasions. There is nothing in the Qur'an and Sunnah that binds the Muslims to a lunar calendar for all purposes, and forbids the use of a solar calendar for other than Ramadan, the *'Idayn*, hajj, etc. Another problematic area is *shahādah*. We must be very clear that though the Messenger Muhammad did not question a witness we are not obliged to accept every testimony. In many situations, the Messenger questioned very prominent companions. Allah rejected all those who blamed A'isha. Ibn Abbas not only questioned Kuraib but rejected both the *shahādah* and *khabar* when it clashed with the actual sighting and forced him to fast 31 days.

46. Elongation is the distance between the sun and a planet, i.e., the angle sun-earth-planet measured from 0° to 180° east or west of the sun. An angle of 0° is called conjunction, one of 180° is opposition.

will be arbitrary) then the observer will see a semi-full moon, and not a crescent.

If the purpose of such an observation is to sight a crescent at the new moon phase from the point of view of the earthbound observer and thus fulfill the requirements of Islam then the experiments performed by NASA are an eye-opener.[47]

• Observed or Defined Crescent

Another suggestion is to go by an assumed observability (though not necessarily visible). The variations of this defined crescent are:

1. The conjunction or the new moon phase: Indonesia, Malaysia, Tunis, Algeria and unofficially Saudi Arabia assume that a crescent is formed at conjunction.
2. One to five minutes after the conjunction at sunset: Egypt officially follows a 5-minute policy, though some want to change it to a 1-minute (Cairo Meeting 1986).
3. A range of hours (18 to 22 hours after the new moon): (Seidelmann, Fadal, and others suggest a range; others suggest a 20- to 45-minute time lag between the sunset and the moonset.)
4. A 5° elongation at sunset (Istanbul Conference).
5. Other variations on parameters like those given above.

Again we face the same dilemma. What is it exactly that we want to define? If it is the *hilal* (the crescent), then we cannot ignore the visibility criterion universally accepted and followed by the Muslim *ummah*. However we define the crescent, will it always be "visible" from the surface of the earth at the defined cut-off point? If not, then how far can it satisfy the Muslims, and how will it be better than the actually visible crescent? The defined crescent may be more "definite" than the observed one but it suffers from all other deficiencies which are associated with the "visible" moon and more. Besides, it is certainly to be resisted by the Muslim *'ulama* and *ummah* because it will be perceived as contradicting the words and the spirit of the Qur'an and Sunnah.

The main advantage of a defined lunar month is that we can precisely calculate the start of the lunar month. But when this advantage is put into practice by drawing the LDL, we run into many difficulties. If the con-

47. Koomen et. al., *Astronomical Journal*, vol. 72 (1967), p. 808.

junction is chosen as the starting time of the Islamic lunar month then we have to start the new month at any hour of the day and night, instead of at sunset as the Qur'an says. Some days of the month will be less than 24 hours and others will necessarily be longer to take care of the fraction. Even then the issue of a shifting LDL is not resolved. If we extend or reduce the day to the next or preceding sunset then we add several more problems. For example, the Islamic day might begin in a few minutes at some places and more than 24 hours later for some others though the two are located in close proximity. Apparently, we have to make many more corrections to keep the definition of the day/date and month in tact. The suggestion to start the Islamic month 1 to 5 minutes after the sunset (Cairo: 1986) suffers from similar drawbacks. Defining the month by a range of moon ages, by the time lag between the sunset and the moonset, or by its elongation (3°–5°) at the sunset are no better than determining the day/date by the conjunction.

Unification of Muslim Dates

Often these suggestions are accompanied by the assertion that all the Muslims should begin their new Islamic month on the same day/date. Those making this plea are driven by their sincere desire to achieve the Muslim unity across all political boundaries. However, it shows their ignorance of some of the basic geophysical facts. At any given instant there are always two solar days/dates on the globe. In reality their suggestion of unity amounts to forcing a solar day/date on an Islamic day/date which are incompatible except for a narrow tropical strip of Muslim lands from Indonesia to Morocco. The Muslims are scattered over all parts of the globe, and we cannot make decisions for a limited group living on one part of the earth, leaving out others on the rest of the earth. If we adhere to the *visible* crescent, as instructed by the Qur'an and Sunnah, the entire Muslim *ummah* will celebrate its occasions on the same lunar Islamic day/date. It will start at the sunset at the first easternmost visibility of the crescent and expand over a 24-hour period from there all over the globe (though this lunar date will span over two solar dates). In essence, nothing is achieved—the Muslim unity or a better calendar—by defining a new Islamic day/date any other way.

• International Lunar Islamic Date Line (ILIDL)

At this point, it is appropriate to discuss the concept of a fixed International Lunar Islamic Date Line. Often it is suggested that the Muslims fix Makkah *Mukarramah* as the meridian for their calendar. The Jews adapted Jerusalem almost two thousand years ago as the meridian for their luni-solar calendar. However, fixing Makkah, or for that matter any other place on land, will equally complicate the matters. Again, it will force the Muslims to define the Islamic day/date and the length of the month. A calendar based on this suggestion will have to make several major adjustments, including celebrating an occasion on two days instead of one on the model of the Jewish calendar. Without these corrections the Muslims will end up having months of 28 to 31 days.

• Kuwait Conference 1973

The recommendations of the Kuwait conference (1973) included the following:

> ". . . the difference of *maṭāli‘* are disregarded among countries separated by long distances as long as they share any part of the night."

Obviously it is not based on a sound understanding of the geophysical and astronomical phenomena. Beside assuming that the earth is flat, the participants believed that the sunset is at the same clock time all over the globe. Had they looked at the globe carefully and checked the rotation of the earth they would have realized that every point on the earth shares the same night with all other points.

• Istanbul Conference (1978)

The Istanbul Conference adopted the principle of unifying the Muslim occasions all over the world on a single day. They also disregarded two fundamental facts: the Muslims are spread all over the globe from New Zealand to Alaska and Norway to New Foundland—they are no longer concentrated in a narrow band of tropical countries from Indonesia to Morocco—and Muslim global unity based on the sighted moon is easier to achieve than on an imposed unity by a defined crescent because the sighted moon is less alien to the Muslim tradition.

• Makkah and Cairo Conferences (1986)

In the Makkah meeting some *'ulama* asserted that a moon could be sighted in Saudi Arabia one or even two days ahead of Tunis and Algeria, as was claimed in several preceding years. However, this is totally against acceptable norms and observational facts. If a moon is really sighted in Saudi Arabia on Monday there is no possibility that it will disappear from view on Monday as well as Tuesday in all regions west of it and then appear again on Wednesday for the rest of the world.

The Cairo Conference recommended to reduce to only one minute the present Egyptian practice of starting the new Islamic month whenever the conjunction occurs five minutes before sunset. Anyone who claims that the moon becomes *visible* from the surface of the earth at conjunction might welcome such a suggestion. However, a closer look at this recommendation reveals that it is a variation of the defined moon stated earlier, and assumes that the LDL will always remain in Egypt. Nobody will agree that a crescent is visible from the surface of the earth at or immediately after conjunction.

Summary of Conclusions and Recommendations

After evaluating most of the available options it appears that the *visible* crescent is still the best criterion for determining the Islamic month and occasions. It is simple, very practical, and easily perfected. It is closer to the word and spirit of the Qur'an and Sunnah, and is in conformity with what the Muslim *ummah* all over the world has understood and followed for the last fourteen hundred years.

For practical purposes and to accommodate the political realities, the lunar date line which appears as a parabolic curve may be extended north/south at the point of first visibility. It will take care of the problem for those regions of the globe in which the lunar crescent may not become visible for obvious reasons such as the sun is too high on the horizon though the elongation of the moon has reached beyond the visibility limits. For small political units, the visibility in the foremost corner may be extended for the entire country, but for larger political entities such as Russia, the USA and Canada, Brazil, Australia, China, India, and even Indonesia, Iran, Saudi Arabia, etc., the visibility may not be extended eastward beyond the local time zone. The plea for Muslim unity (For what reason?) cannot override the fact that the Qur'an and Sunnah require a visible crescent seen from the surface of the earth. Extending the visibility hundreds and thousands of miles east of the sighting to locations where the visibility was out of the question is flouting the Qur'an and Sunnah.

'Ulama must use calculated first visibility for accepting or rejecting the testimony of the witnesses. Hiding behind wrong interpretations of the concept of *ummi*, the 29/30-day tradition, or quoting a *fiqh* which assumes a flat earth by denying the relevance of *ikhtilāf al maṭāli'*, etc., is the root cause of the present confusion. The evidence of visibility and nonvisibility must be accorded equal weight in marginal cases. If the claim of sighting is received from point X which is located east of the point Y and the crescent does not become visible at Y despite clear *maṭla'*, then the claims from X must be disregarded. Similarly, claims by one, two, or a few witnesses on an unobstructed horizon should be closely evaluated.[48]

The present obsession with unity has made many Muslim countries neglect the established geophysical and observational facts. Why should Muslims all over the world celebrate their *'Idayn* and begin their fasting on the same solar day/date instead of the same lunar Islamic date is beyond comprehension.

48. *Nur al-fattah.* See Note 31. There is a simple logic for requiring a large number of witnesses on a clear horizon. If the horizon is clear and hundreds and thousands of eyes are searching for the crescent then only one, two or a few will not see it. A mass observation will take place and at hundreds of places. If a lone witness claims a sighting and nonsighting is confirmed from other places, then he is mistaken.

Data for Crescent Observation

Start of Shawwal 1408
Data for the evening of May 16, 1988
(New Moon Phase: 1988/05/15 22:11 Universal Time)

						MOON'S POSITION AT SUNSET					AT CVL TWILT			
Place	LAT DG MN	LONG DG MN	SUNSET HR MN	MOONSET HR MN	CVTWLT HR MN	AGE HOURS	AZIMTH FROM N	HOR DG FR SUN	ALTIT DEG	ANGLE FR SUN	AZIMTH FROM N	ALTIT DEG	VSBLITY CHANCES	CRIT DIFF
DJAKARTA, INDONESIA	6:17S	106:45E	5:44P	6:00P	6:06P	12.6	64.0W	6.8N	3.7	8.1	64.6W	-1.1	POOR	-0.63
KUALA LUMPUR	3:08N	101:42E	6:17P	6:40P	6:39P	13.1	64.7W	6.0N	5.1	8.4	64.5W	0.3	POOR	-0.49
DHAKA, BANGLADESH	23:45N	90:29E	6:34P	7:11P	6:58P	14.4	65.3W	3.2N	7.5	8.9	63.1W	2.7	POOR	-0.27
NEW DELHI, INDIA	28.40N	77:13E	7:06P	7:49P	7:31P	15.4	65.2W	2.3N	8.3	9.4	62.4W	3.4	POOR	-0.19
KARACHI, PAKISTAN	24:59N	73:05E	6:45P	7:27P	7:10P	15.6	65.4W	2.9N	8.2	9.5	63.0W	3.4	POOR	-0.20
TEHRAN, IRAN	35.:45N	51:30E	7:03P	7:58P	7:32P	17.4	64.8W	0.6N	9.5	10.3	61.0W	4.5	SOME	-0.09
KUWAIT, KUWAIT	29:04N	47:59E	7:33P	8:22P	7:59P	17.4	65.4W	1.9N	9.3	10.3	62.6W	4.4	SOME	-0.10
MAKKAH, S. ARABIA	21:27N	39:45E	6:53P	7:37P	7:17P	17.7	65.6W	3.3N	9.1	10.5	63.7W	4.2	SOME	-0.11
ANKARA, TURKEY	39.55N	32.50E	6.58P	8:01P	7:29P	18.8	64.3W	0.6S	10.1	11.0	59.9W	5.1	SOME	-0.02
CAIRO, EGYPT	30:03N	31:17E	6:42P	7:35P	7:08P	18.5	65.5W	1.6N	9.9	10.8	62.6W	5.0	SOME	-0.04
TRIPOLI, LIBYA	32:50N	13:13E	8:00P	8:59P	8:27P	19.8	65.5W	0.8N	10.6	11.5	62.3W	5.7	HIGH	0.02
RABAT, MOROCCO	33:59N	6:47W	7:22P	8:26P	7:50P	21.2	65.7W	0.2N	11.3	12.1	62.3W	6.3	HIGH	0.09
FRANKFURT, GERMANY	52:20N	14:31E	7:53P	9:21P	8:36P	20.7	60.0W	4.0S	10.4	11.9	52.2W	5.2	HIGH	0.02
ROME, ITALY	41:52N	12:37E	7:24P	8:33P	7:56P	20.2	64.2W	1.4S	10.7	11.6	59.4W	5.7	HIGH	0.04
PARIS, FRANCE	48:51N	2:20E	8:27P	9:50P	9:06P	21:3	62.1W	3.3S	10.9	12.1	55.5W	5.7	HIGH	0.06
LONDON, ENGLAND	51:30N	0:07W	7:48P	9:17P	8:29P	21.6	60.8W	4.1S	10.8	12.3	53.3W	5.6	HIGH	0.06
MADRID, SPAIN	40:26N	3:42W	8:25P	9:36P	8:57P	21.2	64.8W	1.3S	11.2	12.1	60.3W	6.2	HIGH	0.09
ST. THOMAS, VIRGIN	18:21N	64:56W	6:47P	7:46P	7:10P	24.6	65.7W	3.6N	12.4	13.7	64.3W	7.6	HIGH	0.22
ALBANY, NY	42:39N	73:45W	8:12P	9:38P	8:44P	26.0	65.5W	3.2S	13.3	14.4	60.7W	8.1	HIGH	0.30
NEW YORK, NY	40:45N	74:00W	8:08P	9:31P	8:39P	25.9	65.9W	2.6S	13.3	14.4	61.4W	8.3	HIGH	0.30
MIAMI, FL	25:47N	80:12W	8:00P	9:09P	8:25P	25.8	66.4W	1.6N	13.4	14.3	64.2W	8.5	HIGH	0.30
ATLANTA, GA	33:45N	84:24W	8:33P	9:50P	9:00P	26.4	66.6W	0.7S	13.7	14.6	63.4W	8.8	HIGH	0.33
INDIANAPOLIS, IN	39:46N	86:10W	7:54P	9:19P	8:24P	26.7	66.2W	2.5S	13.7	14.8	62.0W	8.6	HIGH	0.34
CHICAGO, IL	41:52N	87:38W	8:05P	9:33P	8:37P	26.9	65.9W	3.2S	13.7	14.9	61.3W	8.6	HIGH	0.34
NEW ORLEANS, LA	29:57N	90:04W	7:47P	9:02P	8:14P	26.6	66.7W	0.3N	13.9	14.7	64.0W	8.9	HIGH	0.34
ST. LOUIS, MO	38:38N	90:12W	8:07P	9:31P	8:37P	26.9	66.4W	2.2S	13.9	14.9	62.4W	8.8	HIGH	0.35
HOUSTON, TX	29:45N	95:22W	8:08P	9:23P	8:34P	27.0	66.7W	0.3N	14.1	14.9	64.0W	9.1	HIGH	0.36
DENVER, CO	39:45N	104:59W	8:09P	9:37P	8:40P	28.0	66.5W	2.8S	14.3	15.4	62.3W	9.2	HIGH	0.39
TUCSON, AZ	32:13N	110:58W	7:16P	8:36P	7:43P	28.1	67.0W	0.6S	14.6	15.4	63.9W	9.6	HIGH	0.41
SAN DIEGO, CA	32:43N	117:09W	7:41P	9:03P	8:09P	28.5	67.0W	0.8S	14.8	15.6	64.0W	9.8	HIGH	0.43
LOS ANGELES, CA	34:03N	118:14W	7:49P	9:12P	8:16P	28.6	67.1W	1.3S	14.8	15.7	63.8W	9.8	HIGH	0.43
PORTLAND, OR	45:31N	122:41W	8:36P	10:17P	9:11P	29.4	65.8W	5.0S	14.5	16.1	60.3W	9.3	HIGH	0.44
HONOLULU, HAWAII	21:19N	157:52W	7:03P	8:21P	7:27P	30.9	66.4W	2.4N	15.8	16.8	64.8W	10.9	HIGH	0.54

Observations made on April 28, 1987 (Tuesday)

Results of Observations (Organized by Mr. Dogget & Seidelmann of U.S.Naval Observatory)

City	ST	No. of Observers	Crescent Sighted	Binoculars Used	Weather
Hanover	NH	1	No		snow
Weston	MA	1	No		snow
Cambridge	MA	4	No		snow
Montpelier	VT	1	No		snow
Glastonbury	CT	1	No		clouds
Stormville	NY	1	No		clouds
Hamilton	NY	1	No		clouds
Ithaca	NY	1	No		clouds
Ocean City	MD	1	No		clouds
Washington	DC	10	Yes & No	Yes & No	haze & clo
State College	PA	3	No		clouds
Easton	PA	1	No		clouds
Blackstone	VA	2	Yes & No	No	
Chapel Hill	NC	1	No		clouds
Greenville	NC	1	No		clouds
Boone	NC	17	Yes & No	Yes & No	clear, haze
Tampa	FL	3	No		clear, haze
Fort Myers	FL	1	Yes	Yes	
Atlanta	GA	2	No	No	clear
Macon	GA	1	No	No	haze
Columbus	OH	1	No	No	cloudy
Warren	MI	1	No		clouds
Lansing	MI	1	Yes	Yes & No	haze
Tuscaloosa	AL	1	No		haze
Chicago	IL	5	No		clear
New Orleans	LA	1	Yes	No	
St. Louis	MO	1	No		clouds
Columbia	MO	7	No		clouds
Des Moines	IA	1	No	Yes	vapor tra
Austin	TX	2	Yes		
Mt Locke	TX	82	Yes	Yes & No	
Denver	CO	1	No		clouds
Rocky Ford	CO	1	No		clouds
Socorro	NM	1	No		haze
VLA	NM	2	No		clouds
Tucson	AZ	1	No		clouds
Flagstaff	AZ	1	No		clouds
Salt Lake City	UT	1	Yes	Yes	cloud bar
Walla Walla	WA	10	No		thunderst
Costa Mesa	CA	1	No		clouds
Santa Barbara	CA	2	No		clouds
Oakland	CA	1	No		fog
Los Angeles	CA	1	No		cloudy
Pasadena	CA	2	No		fog
Mt Hamilton	CA	1	Yes		clouds
Victoria	BC	1	No		

■ معهد الارصاد يؤكد :

ميلاد هلال شهر رمضان حدث فجر امس فلكيا

تؤكد الحسابات الفلكية التي اجراها المعهد القومي للبحوث الفلكية والجيوفيزيقية بحلوان ان ميلاد هلال شهر رمضان المعظم لعام ١٤٠٧ هجرية قد حدث في تمام الساعة الثالثة والدقيقة ٣١ من فجر امس الموافق ٢٨ ابريل ١٩٨٧ وان لحظة الميلاد هذه تعد لحظة كونية اي ان الهلال يولد عن العالم كله في لحظة واحدة وموحدة .

ويصرح الدكتور ... مدير المعهد بانه يترتب على ذلك تاكيد السيد ان بداية شهر رمضان لهذا العام هو ٢٩ ابريل وان اي شهادات بثبوت رؤية الهلال قبل فجر امس لاتستند الى اي حقيقة واقعية او علمية .

مشکل یک شام سائنسی لحاظ سے چاند نظر آنا

ناممکن تھا: ماہرین فلکیات کی رائے

[illegible]

غدا اول شهر رمضان المعظم

اليوم هو المتمم لشهر شعبان

لم تتمكن دار الافتاء امس ، من رؤية هلال شهر رمضان المبارك لعام ١٤٠٧ هجرية . وعلى ذلك فقد اعلن الدكتور محمد سيد طنطاوي مفتي الجمهورية ، ان اليوم الثلاثاء هو المتمم لشهر شعبان . وان غدا الاربعاء هو اول ايام شهر رمضان المعظم .

وكانت دار الافتاء قد اجرت اتصالات امس مع عدد من الدول العربية والاسلامية الشقيقة المتفقة مع مصر في نفس خط العرض . كما استمعت الى شهادة العلماء ومندوبيها في الاماكن المتفرقة على جميع انحاء الجمهورية ، وكذا تقرير رجال الارصاد الجوية ، واكدت كلها عدم رؤية الهلال .

وكانت كل من السعودية وقطر والبحرين والكويت ولبنان والاردن قد اعلنت ان اليوم الثلاثاء هو اول ايام شهر رمضان المبارك بينما اعلنت بغداد وتونس ان غدا الاربعاء هو اول ايام الشهر المبارك .

Egpyt has a solar eclipse on March 29, 1987. How could they really SEE a crescen:

A Review of the Principles of the Islamic Calendar and a Proposal for Establishing a Reliable International Islamic Calendar

Abdur Rahim Khan

Abstract

This paper reviews the geometry of crescent formation and the psychology of vision. The maximum width of the crescent is calculated, and an equal visibility criterion for clear sky conditions is developed for the determination of the start of an Islamic month. The proposed criterion accounts for the latitude and longitude of the observer, and the actual ellipticity and tilt of the lunar orbit. The concept of a date line is reviewed and an Islamic date line with global validity is proposed for the establishment of an international Islamic calendar. This paper is deliberately written in layman's terms. It is assumed that the reader knows only high school level mathematics and has no prior knowledge of astronomy.

Introduction

At this time Muslims have no definite calendar. Some of them feel that it is impossible to make one because there is something unpredictable about the motion of the moon. This causes a great deal of argument and confusion in the Muslim community and is embarrassing for all of us. While others have visited the moon and have planted their standard there, every Ramadan Muslims indulge in acrimonious debate over where it is. In reality, the calendar based on the Qur'an that was established during the days of the Prophet Muhammad is quite definite and can be used internationally if we get organized and agree upon certain conventions. Because this has not been done each community and often individuals make up their own rules resulting in an argument over what day of the month it is. Europeans went through a similar phase in the last century. As they started traveling great distances quickly, there was confusion over dates. Soon a date line was agreed upon among the leaders and the common man was merely informed after the decision. Now, because of the general availability of telecommunication, every Muslim is involved in this debate. However, the lunar cycle is not as obvious as the solar cycle of day and night. Many people do not realize that just as we cannot find whether it is day or night at our location by phoning the home country, we cannot be certain about a lunar date confirmed by another half a world away. One has to look at the local sky. Every Muslim is not an astronomer, he cannot rationally decide about such matters. His decisions are generally based on emotional and devotional reasons and are often scientifically wrong. It is essential that the community pay urgent attention to solve this problem.

SOME COMMENTS ON THE MOTION OF HEAVENLY BODIES

The relative motion of all heavenly bodies is governed by a few simple laws commonly known as Newton's laws of motion and the law of gravity. The curved path of a body through the heavens is such that gravitational force is always balanced against (i.e., equal and opposite to) the centrifugal force due to the curvature of the path and the inertial force due to the acceleration of the body. As a result, planets generally move in an elliptic orbit around the sun such that the sun remains at one of the foci of the ellipse. A circular orbit is just a special case of an ellipse when the two foci are congruent. The two equations that have to be solved simultaneously for computing the orbit of a planet are as follows:

$$\text{Gravitational force} = G \cdot M1 \cdot M2/R^2 \quad (1)$$

$$\text{Acceleration of a body} = G \cdot M2/R^2 \quad (2)$$

Here G is the gravitational constant, M1 is the mass of the planet, M2 the mass of the sun, and R is the instantaneous distance between them.

For a two-body system the method of solution is quite simple. As the number of bodies increases it becomes increasingly difficult to solve these equations. But all this has been done by modern computers, and tables giving relative positions of bodies in our solar system are available in most libraries. To construct a calendar, all one has to do is to learn to read and use them.

THE EARTH, MOON AND SUN SYSTEM

The Qur'an says that the sun and the moon move according to a *ḥisāb*, i.e., governing laws. These laws have been known in detail for some time so that we may be confident that we know the location of a heavenly body at any given time. This is all that is needed to construct a prayer timetable and a calendar. A calendar can be viewed as a special prayer timetable that tells us when to say *tarawīḥ* or *Īd* prayers.

MOTION OF THE EARTH

Basically, the earth moves in three ways.

1. It spins on its axis to produce day and night. This takes 24 hours. Its spin axis is tilted about 23.5 degree in relation to its orbital plane.
2. It revolves around the sun in a near circular orbit. Because of the tilt of its rotational axis the sun appears to move north and south through the year. This change in the angle of incidence of light from the sun is responsible for the change of seasons. Its rotational period is about 365.25 days or roughly a year. This necessitates frequent correction in the length of the solar year to prevent the seasons from sliding through the year. This is done by means of a system of having leap years (366 day years) every four, one hundred, four hundred, and four thousand years. This also corrects for fractional number of days in a solar year.
3. A third, less known, motion of the earth is called precession. The axis of rotation describes a cone in space over a period of about 25,800 years.

MOTION OF THE MOON

The moon moves under the influence of gravity, mainly, of the sun and the earth. It is also disturbed slightly by other planets. Its orbit around the earth is only approximately elliptic because the sun disturbs it. Its orbital plane is tilted-in relation to the earth's orbital plane (ecliptic) by about 5 degrees. The moon's orbital plane is not fixed in space in relation to the stars. Even though it maintains a constant tilt in relation to the earth's orbital plane, the line of intersection of these two planes (nodes) rotates slowly in space. Because of the tilt of its orbit the moon appears to move to the north and south of the sun, and the new crescent is sometimes seen to the left and at other times to the right of the setting sun. Viewed from space the path of the moon is like a sine wave superimposed over the near circular path of the earth.

The moon produces no light of its own and shines due to sunlight. Like earth, only half the surface of the moon's sphere is illuminated by the sun at any time. Depending upon the relative position of the three bodies we can see varying portions of the illuminated side of the moon from the earth. When the moon is between the earth and the sun only the far side of the moon is illuminated and we cannot see it. This position is called astronomical new moon. When the earth is between the moon and the sun and the side of the moon facing us is illuminated by the sun, we see full moon. Viewed from the moon, the earth appears to change phases much like the moon. Figure 1 shows the sphere of the moon and the relationship of the directions of the sun and the earth at the time of first visibility of the crescent.

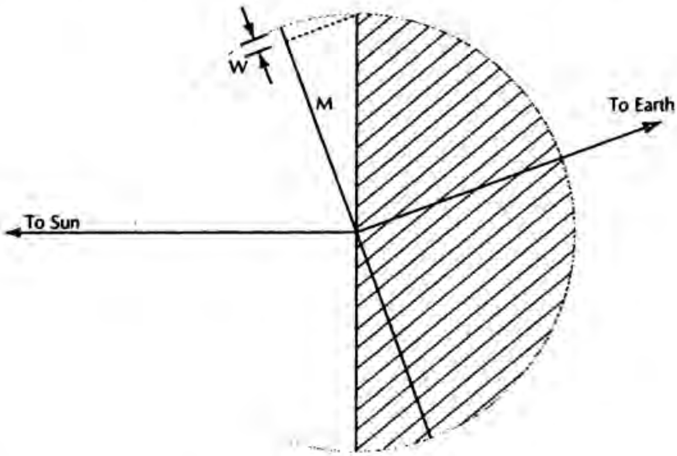

Figure 1.

From this diagram it can be seen that the width of the crescent (w) that can be seen from earth is $r\cdot(1\text{-Cos } M)$. Here r is the radius of the moon's disk and M is the angle between the lines of sight from the earth to the sun and the moon. Since the moon appears to move about 360 degrees around the earth in relation to the sun in one month (about 29.5 days) its apparent daily motion is about 12.2 degrees on the average. Because of the ellipticity of the moon's orbit this number varies from 11.5 to 13.1 degrees a day. Earliest visibility is possible when the moon is closest to the earth and the angle from the sun is changing fastest. Therefore, the greatest angle $M = 13.1\cdot A/24$ degrees. Here A is the age of the moon or the time from astronomical new moon in hours. In radians $M = 13.1\cdot A\cdot 3.14/24\cdot 180$ or about

0.00952·*A*. Since Cos $M = 1 - M^2/2$ when M is small, the width of the crescent of age A hours as seen from the earth can be approximated as follows.

$$\text{Width} = r \cdot (0.00952 \cdot A)^2/2 \tag{3}$$

Since the minimum distance of the moon from the earth is about 357,000 km and $r = 1{,}738$ km, the angle subtended by the widest part of the crescent on the eye of an observer on earth is its width divided by the distance. Therefore,

$$\text{Angle} = 1738 \cdot (0.00952 \cdot A)^2/2 \cdot 357000 \text{ radians} \tag{4}$$

$$= 0.045 \cdot A^2 \text{ seconds of arc} \tag{5}$$

Hence it is seen that the width of the young crescent is proportional to the square of its age. The constant 0.045 is just an estimate, it depends on the distance of the moon from the earth. Since the resolving power of the human eye is about 20 seconds of arc (1 second of arc is 1/3600 degrees) the approximate age of the crescent for visibility can be estimated from equation (5) as follows:

$$20 = 0.045 \cdot A^2 \tag{6}$$

or $$A = 21 \text{ hours.}$$

This is the basis for the much talked about 20- or 22-hour rule for the earliest visibility of the crescent. In the tropics, if the age is much more than this, one can be sure that it will be seen, and if it is much less than this we can safely say that it will not be seen. Because of a number of other factors, visibility of the crescent actually varies with a much higher power of age than the square law derived from geometry only. They are discussed later.

MOTION OF THE SUN

The sun also moves in relation to other stars in our galaxy, but the entire planetary system moves with it. Since our interest is limited to relative motion of the earth-moon-sun system we do not have to concern ourselves with the motion relative to other stars.

ISLAMIC CALENDAR CONVENTIONS: RELIGIOUS REQUIREMENTS

The Qur'an clearly says that the sun and the moon move according to laws and are used for the reckoning of time. There has always been a tendency among common people of all faiths to ascribe some mystical meaning or significance to their appearance and motion. The Qur'an does not support such a view—to the Muslim, they are nature's clocks.

Islamic conventions about time keeping are different from those in common use in the western world today. For example, to a Muslim a day begins at sunset, not midnight. A week, month, and year are similarly affected.

The 12 Islamic months are not of fixed duration; for example, Muharram can sometimes be 29 days and sometimes 30 days. The month starts with the first visibility of the new moon and not with the birth of the moon or with the astronomical new moon as in some other calendars.

Calendars can be based on either the motion of the moon, the sun, or both. Most lunar calendars are luni-solar, that is, although they count a month based on the lunar cycle, they introduce some corrections to keep their calendar synchronized with the seasons that depend on the solar cycle. Usually, this is done by adding a 13th month every few years, and is known as intercalation. The Qur'an forbids intercalation, and clearly states that a year has 12 months. Since a lunar month on the average has about 29.5 days, the Islamic year has only 354±1 days. This injunction leaves the Islamic year about 11.25 days shorter than the average solar year. For this reason our observances move through the seasons and come about 11 days earlier in each succeeding year.

THE PSYCHOLOGY OF VISION: HOW DO WE SEE THINGS?

Visibility is not only the property of an object, it is the result of the interaction between an object and its surroundings with an observer in the presence of a light source. We see things when a sufficient amount of light bounced off an object is able to reach our eyes. Based on everyday experience we can say that an object becomes visible if the following two conditions are met:

- It is big enough—very small things cannot be seen; and

- Its illumination is significantly different from its surroundings. For example, white on white is invisible, black on white is very visible, and gray on white is less visible.

Therefore, visibility to a man with good eyesight depends on contrast and size. As discussed earlier, the width of the crescent depends on its age. Because an older crescent remains above the horizon longer after sunset its contrast in relation to the darker sky of later evening also increases. This further aids visibility.

ACUITY OF VISION

As indicated earlier, a person with normal vision can resolve down to about 20 seconds of arc. That is, he can recognize those visual details in a scene that subtend an angle greater than 20 seconds of arc at his eye if sufficient contrast is present. Objects smaller than this appear to be of this size but at a reduced contrast. If a finer (less that 20 seconds of arc wide) black line is drawn on white paper, it appears wider but gray to us. Similarly, a source of light smaller than this number appears bigger but less bright to us.

The approximate criterion of visibility based on size alone was previously developed under the topic "Motion of the Moon." For completeness, that is, to get the precise theoretical condition for visibility it has to be combined with the contrast requirement. I say theoretical because even after we account for standard atmospheric conditions there is no guarantee of sighting because actual atmospheric conditions are variable and unpredictable.

DEFINITION OF CONTRAST AND THINGS THAT AFFECT IT

Contrast between two parts of a scene is defined as the ratio between the difference of their illumination and the sum of their illumination. Symbolicly, we may write it in the following form:

$$\text{Contrast} = (IMAX - IMIN)/(\text{IMAX} + IMIN) \qquad (7)$$

Here *IMAX* and *IMIN* are the maximum and minimum illuminations in a scene.

Our atmosphere greatly reduces contrast because of two effects. Without an atmosphere the sky would appear black, i.e., *IMIN* would be zero, and *IMAX* would be much higher because all the light from the moon would reach us without being absorbed or scattered by the atmosphere.

Atmospheric absorption and scattering characteristics are highly variable and unpredictable. While it is possible to characterize for an existent atmosphere very accurately, it is not possible to predict what a future atmosphere will be like because, besides the innumerable unpredictable natural phenomena, there are also affects caused by human activity. Minute and often imperceptible changes in the atmosphere can affect contrast immensely. For example, it is a matter of common experience that the sunset looks different every day even when the atmosphere appears clear. The following section analyses the effect of atmospheric changes in a more quantitative way.

Absorption and Scattering by the Atmosphere

The equations of atmospheric absorption can be developed easily with the help of Figure 2 below.

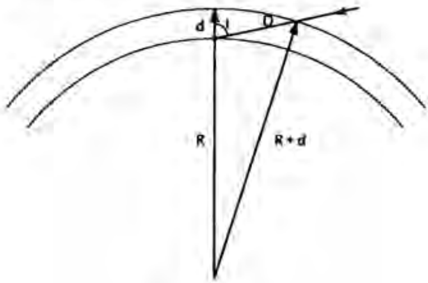

Figure 2.

If *R* is the radius of the earth and *d* is the vertical depth of the atmosphere, the distance, *D*, a slanting beam of light has to travel through the atmosphere before reaching ground can be calculated from the cosine law of triangles as follows:

$$R^2 + D^2 + 2R \cdot D \cdot \mathrm{Cos}(I) = (R + d)^2 \qquad (8)$$

Here *I* is the angle of incidence from the vertical. Solving for *D* gives:

$$D = - R \cdot \mathrm{Cos}(I) + (R^2 \cdot (\mathrm{COS}(I))^2 + d^2 + 2R \cdot d)^{1/2} \qquad (9)$$

Table 1 (placed at the end of this paper) gives values of *D* for various values of *I*. If the vertical depth of atmosphere *d* is assumed to be 5 miles, at sunset the light would have to travel about 197 miles through our atmosphere and much of it would get absorbed or scattered. It is for this reason that the sun appears so dull at sunset. The magnitude of this absorption can be calculated from the standard logarithmic law, i.e., each thickness of atmosphere reduces transmission by a fixed ratio. For example, if we assume that only 70% of sun's light reaches us when the sun is overhead, only 0.7·0.7, i.e. 49% of it will reach us in case of a slanting entry when $D = 2d$. At the time of sunset when D is about $40 \cdot d$, the fraction that will be able to reach us will be only 0.7 to the power 40 = 6E-7, i.e., only 0.6 parts per million will reach us. If the atmospheric absorption is changed only 10% such that 77% of light is able to reach us for vertical incidence, the amount reaching us at sunset will be 0.77 to the power 40 = 2.88E-5. This is 48 times more than the previous case. It should now be obvious why the sunset looks so different every day even though the sky appears clear. Table 2 lists values of transmission through the atmosphere for various angles of shallow incidence and atmospheric absorption coefficients.

Frans Bruin has reported values of brightness for various altitudes of full moon.[1] They agree well with my theoretical development for estimating transmission through the atmosphere.

Illumination of the Sky after Sunset

This is best determined experimentally. Frans Bruin has reported values of illumination for various solar dip angles.[2] If necessary, fresh measurements can be taken with better instruments. It is necessary that this function be agreed upon for the development of the calendar.

Actual Contrast of the Moon as Seen from Earth

Illumination of the moon as seen from the earth is the sum of transmitted light of the moon and the illumination of the sky. Therefore:

$$IMAX = IMOON \cdot F(I) + ISKY. \qquad (10)$$

Here *IMOON* is the original illumination of the moon before reaching the atmosphere, $F(I)$ is the transmission function of angle of incidence I (as given in Table 2 or whatever function is ultimately chosen), and *ISKY* is the illumination of the atmosphere.

$$IMIN = ISKY \qquad (11)$$

1. Frans Bruin, "The First Visibility of the Lunar Crescent." *Vistas in Astronomy* (Great Britain: Pergamon Press) 21 (1977): 331–358.

2. Ibid.

Therefore, contrast of the moon as seen from the earth is given by the following expression:

$$\text{Contrast} = IMOON{\cdot}F(I)/(IMOON{\cdot}F(I) + 2{\cdot}ISKY). \qquad (12)$$

IMOON·F(I) can be measured, once *F(I)* and *ISKY* are standardized, and contrast can be calculated for all configurations of the sun and the moon near sunset.

At the time of sunset the illumination of the sky is too high. From equation (12) it can be seen that for high *ISKY* the contrast is low and the moon cannot be seen. As the evening progresses, *ISKY* reduces and the contrast improves. Later as the moon approaches the horizon, its light is increasingly absorbed by the atmosphere and the portion reaching us declines very quickly. Hence the contrast starts reducing after reaching a maximum value, and continues to do so until the moon sets.

Combining Size and Contrast Data

Experimentally determined values of minimum contrast required to make an object just visible are available in at least two forms. One experiment involves the use of disks of various sizes and shades, and the other is based on the use of sinusoidally varying grating. Both produce data that can be reduced to a simple curve of size vs. minimum contrast required for visibility. Once the size of the crescent is known, the condition for visibility is reduced to comparing this number with the highest contrast achieved during the evening as determined from equation (12). If the achieved contrast is greater than the minimum required, the moon should be declared visible.

CAN THE VARIATION IN THE ATMOSPHERIC CONDITION BE ALLOWED TO INFLUENCE THE CALENDAR?

As indicated earlier weather and atmospheric phenomena cannot be predicted at the present time with any degree of certainty. Even if later technology can predict them with greater accuracy, the noncyclical nature of changes in weather will remain. Because of the unpredictability of weather, much confusion is introduced by some people on religious grounds. Comments like "We told you the moon is unpredictable" are often heard. Some people insist that we have to delay the arrival of a month in case of clouds. Such an interpretation of certain hadith is not only contrary to the Qur'an but also to common sense. Surely, it would be silly for Muslims to have a calendar based on clouds. If no other information is available to determine the condition of the moon, it is prudent to err on the safe side. But it is wrong to allow the randomness of clouds to take precedence over the firmly established and known cyclical motion of the moon. If we believe in the Qur'an and accept that the moon is for the reckoning of time, it would be wrong to introduce the absence or appearance of clouds and fog as a necessary element in time keeping. For these reasons I firmly believe that contrast calculations should be based on some standard clear atmosphere only.

DEVELOPMENT OF THE INTERNATIONAL LUNE DATE LINE

Just as there is a solar date line (180 degrees longitude) to mark the start of a date on a solar calendar, a lunar date line can be constructed to indicate the start of a lunar date. Because an Islamic month begins in the evening with the first visibility of the crescent, these points of first visibility can be considered to constitute the lunar date line.

For a given solar dip angle and angular separation between the moon and the sun, the moon appears higher above the horizon at sunset near the equator than at high latitudes. For this reason higher contrast is achieved in the tropical region. As we move to higher latitudes, because of reduced contrast, a bigger crescent is required for visibility and visibility is delayed. For this reason the line of first visibility appears like a parabola enlarging towards the west.

NEED FOR A MODIFIED DATE LINE

Since the earth's spin axis is tilted to an angle of 23.5 degrees, and the moon's orbital plane is further tilted about 5 degrees to the earth's orbital plane, the moon cannot be expected to come above the horizon every month at latitudes greater than approximately 90 - (23.5 + 5) = 61.5 degrees. Further, in such places the sun may appear higher than the moon, and visibility may be impossible. I say "may be" because the conditions vary from month to month. Even at somewhat lower latitudes where visibility may be possible it may be delayed so much that the months become shorter and longer than 29 and 30 days. Obviously, such a situation is not acceptable and some other criteria are required to determine the start of a lunar month at high latitude. In practice, the problem starts near 50 degrees latitude. For example, Muharram 1408 becomes 31 days near 50 degrees North latitude. For this reason I propose that the local visibility requirement be abandoned at latitudes higher than 45 degrees (Toronto is at 44 degrees), and the lines of longitude be treated as the Islamic date lines from this latitude to the poles. Once we adopt this convention a lunar calendar can be constructed for all places on earth; otherwise, much of Canada will be without an Islamic calendar. When Ramadan and the two *Īds* take place in the Winter, confusion will increase because the crescent will not be seen on time over much of Canada even in clear weather.

Approximations for Simplifying the Calculations

The exact method described above is too complex for people not trained in astronomy and mathematics. The labor and skill required for constructing such a calendar can be justified only if the product is widely used around the world. Further, even if the method proposed here ultimately gains general acceptance it may take many years to accomplish. In the interim a simpler method that can be used to construct a local calendar quickly is needed for use by communities who choose to implement it on their own. The present state of utter confusion is too painful and embarrassing for most of us. Even the 20-hour visibility criterion is more reliable and accurate than what we have been able to achieve by reliance on rumors of sighting from far away places.

Once we realize that for any locale the average age for sighting is about 32 hours, and the range is from about 20 hours to 20 hours plus a day, i.e., 44 hours, it becomes obvious that there can only be a few months for which accurate calculation may be required because the age of the crescent is close to 20 hours. For most months there is no doubt about visibility because the age is considerably more that 20 hours. For those months where the age is close to 20 hours the question of contrast can be answered quite reliably if the elevation of the moon above the horizon is known at sunset, or the time difference between sunset and moonset is known. If the moon is more than 20 hours old and remains above the horizon for more than 30 minutes after sunset, it is our experience that it can be seen. In Toronto we have relied on the 20-hour age in combination with minimum 30-minute time difference between sunset and moonset as a criterion for visibility for many years. Based on more than 10 years of experience we can report that the method has never failed. The Hilal Committee of

Toronto and Vicinity uses this method for developing the calendar for local use.

THE INTERNATIONAL ISLAMIC CALENDAR

There are two practical difficulties with the use of the precise date line developed here.

1. The Islamic date line is different every month. In general it passes through land masses and may divide countries and even large cities into regions of two different dates. This is very inconvenient and is not likely to be accepted by people.
2. Because the international date line is fixed and the Islamic date line revolves around the globe, in general an Islamic date straddles two Gregorian dates and vice versa. Unless some other adjustment is made in the Islamic date line it is impossible to ensure observance of any Islamic festival on one day throughout the world.

If we adopt a convention that the Islamic date line will be moved to the nearest ocean (Atlantic or Pacific as the case may be) the first problem will be solved almost completely, and on the average, half the observances will be on the same day throughout the world. I personally do not consider observance on one Gregorian date very important, but because certain groups feel that this is an essential element for Muslim unity, I have suggested a systematic way of achieving this condition. Other schemes proposed by fiqh committees are not worthy of discussion.

Table 1.

Angle of Incedence	Length of Transmission	Fraction Transmitted
0	5.0	.7
2	5.00317	.699842
4	5.01221	.699391
6	5.02734	.698636
8	5.04907	.697554
10	5.0769	.69617
12	5.11133	.69463
14	5.15283	.69241
16	5.20117	.690026
18	5.25684	.687292
20	5.32031	.684187
22	5.39185	.680704
24	5.47217	.676815
26	5.56152	.672515
28	5.66138	.667742
30	5.77124	.662529
32	5.89356	.656773
34	6.02832	.65049
36	6.17676	.643638
38	6.34106	.636138
40	6.52222	.627971
42	6.72241	.619066
44	6.94409	.609354
46	7.18994	.59876
48	7.46338	.587194
50	7.76782	.574579
52	8.10816	.560798
54	8.49097	.545691
56	8.92285	.529135
58	9.4126	.510968
60	9.97217	.490974
62	10.616	.468936
64	11.363	.444599
66	12.2385	.417682
68	13.2771	.387856
70	14.5264	.354787
72	16.0547	.318141
74	17.9637	.277636
76	20.4105	.233172
78	23.6506	.185052
80	28.1293	.134444
82	34.6891	8.42012E-02
84	45.1112	4.00348E-02
86	63.7472	1.05947E-02
88	103.036	6.42559E-04
90	196.903	7.9411E-07

Table 2.

Fraction of Light Transmitted through the Atmsosphere at Different Angles

0°	84°	86°	88°	90°
.6	9.96388E-03	1.48441E-03	2.68121E-05	1.83435E-09
.605	1.07386E-02	1.65008E-03	3.18128E-05	2.5434E-09
.61	1.15663E-02	1.83264E-03	3.76931E-05	3.51705E-09
.615	1.24504E-02	2.03365E-03	4.45984E-05	4.85058E-09
.62	.013394	2.25481E-03	5.2697E-05	6.67233E-09
.625	1.44006E-02	2.49796E-03	6.21828E-05	9.15482E-09
.63	.015474	2.76506E-03	7.32794E-05	1.25293E-08
.635	.016618	3.05827E-03	8.62442E-05	1.71052E-08
.64	1.78365E-02	3.3799E-03	1.01373E-04	2.32952E-08
.645	1.91339E-02	3.73244E-03	1.19006E-04	3.16492E-08
.65	2.05145E-02	4.11861E-03	1.39533E-04	4.28974E-08
.655	2.19829E-02	4.54129E-03	1.63402E-04	5.80079E-08
.66	2.35441E-02	5.00364E-03	1.91124E-04	7.82612E-08
.665	2.52032E-02	5.50903E-03	2.23285E-04	1.05347E-07
.67	2.69653E-02	6.0611E-03	2.60554E-04	1.41493E-07
.675	2.88362E-02	6.66375E-03	3.03695E-04	1.89624E-07
.68	3.08216E-02	7.3212E-03	3.53579E-04	2.53579E-07
.685	3.29277E-02	8.03798E-03	4.11198E-04	3.38383E-07
.69	3.51608E-02	8.81893E-03	4.77683E-04	4.50601E-07
.695	3.75275E-02	9.66929E-03	5.54316E-04	5.98795E-07
.7	4.00348E-02	1.05946E-02	6.42558E-04	7.94107E-07
.705	.04269	.011601	7.44064E-04	1.05101E-06
.71	4.55006E-02	1.26948E-02	8.60713E-04	1.38827E-06
.715	4.84746E-02	.013883	9.94633E-04	1.83018E-06
.72	5.16202E-02	1.51729E-02	1.14823E-03	2.40812E-06
.725	.054946	1.65725E-02	1.32423E-03	3.16254E-06
.73	.058461	1.80902E-02	1.52571E-03	4.14554E-06
.735	6.21745E-02	.019735	1.75615E-03	5.42405E-06
.74	6.60963E-02	2.15168E-02	2.01947E-03	7.08394E-06
.745	7.02366E-02	2.34457E-02	2.32009E-03	9.23518E-06
.75	7.46058E-02	2.55329E-02	2.66298E-03	1.20184E-05
.755	7.92151E-02	2.77902E-02	3.05375E-03	1.5613E-05
.76	8.40759E-02	3.02301E-02	3.4987E-03	2.02477E-05
.765	8.92001E-02	3.28661E-02	4.00491E-03	2.62135E-05
.77	9.46002E-02	3.57124E-02	4.58033E-03	3.388E-05
.775	.100289	3.87845E-02	5.23387E-03	4.3716E-05
.78	.10628	4.20984E-02	5.97553E-03	5.63153E-05
.785	.112587	4.56716E-02	6.81651E-03	7.24285E-05
.79	.119225	4.95224E-02	7.76936E-03	9.30034E-05
.795	.126208	5.36705E-02	8.84809E-03	1.19235E-04
.8	.133553	5.81367E-02	1.00684E-02	1.52627E-04

INTERNATIONALIZATION OF NEW MOON SIGHTINGS FOR THE ISLAMIC LUNAR MONTH

Hussein Kamal Eddine

(Translated from Arabic by Fakhreddine Karray)

Introduction

In order to establish a lunar calendar, all variables related to the computation of the visible new moon should be taken into account. Some of those variables, which are controlled by the forces of God, occur regularly and are subject to the rigorous laws of astronomy.

Others, which are known exactly only by God, depend on many factors such as the optical resolution degree of the eye observer, and weather parameters: humidity, temperature, fog, purity of the air, clouds, etc.

Nevertheless, it is possible by means of estimation and statistical laws to recognize to a certain extent the effect of such nonregular variables. In any case, it is not comparable to the eternal natural rules of God which can be proved mathematically.

International Lunar Calendar

It is well known that the establishment of any lunar or solar calendar in advance requires the knowledge of rules and parameters that determine this calendar. For example, the solar calendar that is internationally used takes the meridian passing through the Greenwich observatory as the principle longitude. (In some old atlases the principal longitude was the meridian passing through Paris.) In this solar calendar, the solar day begins usually at 12 o'clock midnight at the Greenwich longitude.

All the eastern domain of this line is later in time than the western domain. By this convention, also, there is between 180° W and 180° E the time difference of a whole day. In this same calendar, the year is divided into twelve nonequal periods called "months."

One of them is 28 or 29 days, others are simply 30 or 31 days without any astronomical motivation. In order to eliminate the appearance of a fractional day during a solar year, a year is taken to be 365 or 366 days according to certain conventions. The time in the solar calendar in a given place is not the "real" local time but, rather, the average called "civil" time.

As with the solar calendar, the lunar calendar can be used as an international and recognized calendar provided some conventions are employed. Some people who are accustomed to the solar calendar find the idea of establishing an international lunar calendar elusive, not noticing that the actual solar calendar is purely a matter of international convention.

As we know, the solar calendar is directly linked to human activity. The daily apparent rotation of the sun in the sky makes the day and the night. Also, the rotation of the earth around the sun determines an astronomical year and is responsible for the changing of the seasons—which is itself responsible for plant activity and weather dynamics (variation of temperature, motion of winds, rain, and so on).

The lunar month, on the other hand, is an astronomical revolution which has been chosen by God on Genesis day. In addition, twelve lunar months are defined by Him to be a lunar year.

> The number of months in the sight of God is twelve (in a year) so ordained by him the day he created the heavens and the earth, of them four are sacred. (9:36)

In the lunar calendar, the lunar month is defined by the motion of the sun (apparent) and the motion of the moon, whereas in the solar calendar the month is defined by a number of days.

Also, in the lunar month the day begins after sunset, whereas in the solar calendar the day is a time duration between two midnights. By this latter convention, a given night is common to two consecutive days, the first half of the night belongs to the current day, the other half belongs to the following day and so on.

The lunar calendar is linked to religious and civil matters, for example:

- starting the month of fasting (Ramadan), which corresponds to the first visible crescent in the month of Ramadan;

- ending the month of fasting, which corresponds to the first visible crescent in the month of Shawwal and the beginning of *Īd al Fitr* each lunar year.
- the sacred months which are Shawwal, Dhu al Qa'dah, Dhū al Ḥijjah (in which the *Hajj* is performed), and Rajab.
- standing on the plain of *'arafat* during the *Hajj* which is the ninth day of Dhū al Ḥijjah and followed by *Īd al Aḍḥā* on the tenth, eleventh, twelfth day (corresponding to the pilgrims' stay at Mina during the *Hajj*).
- the first visible crescent of Muharram, signaling the beginning of the lunar year;
- In addition, the lunar calendar is linked to a certain type of communication and relationship among people and counting around the world.

In Muslim countries, the legal lunar month begins as the new crescent becomes visible with the naked eye after sunset of that day.

If a natural obstacle is present, we determine the beginning of the month by prediction based on mathematical computation. As the Prophet stated: "If you don't see it, make your best guess to affirm whether it is present or absent."

Because of the noncommensurability between the proper rotation of the earth and the rotation of the moon around the earth, the beginning of lunar months cannot occur each year at the same time and place.

To fix this problem (as has been done for the solar calendar when Greenwich was chosen as standard longitude) we suggest that the computation of the lunar calendar be based on the geographical position of Makkah. For other places the same kind of computation leads to the determination of which we call curve of polarity of rising of the sun and the moon. Makkah is chosen as the standard place of computation due to many religious and historical considerations.

At the same time, this lunar calendar would help us in simplifying our worship and civil life. In order to establish an international lunar calendar, all the following factors should be well known and studied:

1. Motion of the moon around the earth (synodic revolution).
2. Motion of the earth with respect to the sun during each lunar month.
3. Increasing delay between moonset and sunset time, until becoming one whole day, which means the moon returns back to the state of conjunction with the sun.
4. Sufficient angular separation between moon and sun after conjunction, which allows in good meteorological condition and persistent observation, the sighting of the moon at twilight.

The first, second, and third factors stated above are well-known astronomical facts, and can be computed with a very high degree of precision. However, the fourth factor depends on two parameters.[1]

1. An astronomical horizon which can be defined experimentally, and depends only on the diffracted sunlight at the horizon and on the time of sunset.
2. A natural horizon which depends on meteorological factors such as clouds, fog, air purity, temperature, humidity, and other factors that cannot be computed and predicted with high precision. It depends also on the optical resolution ability of the observer. This last factor was precisely the origin of discord among previous astronomers. In fact the sight of the first crescent is possible between 7 and 22 hours after moon conjunction, which corresponds to less than half-hour time between sunset and moonset.[2]

In establishing an International lunar calendar this amount of time should be in agreement with experimental dates to avoid any discord among astronomers in every place on the globe.

Determination of Lunar Month Starting Date

The easiest way to compute the beginning time of lunar months is summarized in the following steps:

1. Compute the occurring time of conjunction in universal time. (This date and time can be found in astronomical ephemerides; otherwise, it can be computed as the time of common longitude for the moon and the sun.)
2. Add to that the required time to see the new crescent while it is still far enough from the sunset horizon.
3. If the total exceeds 24 hours then expect the sighting to be on the following day; and therefore subtract 24 hours and add one day to the date given by the ephemeral.
4. Compare the remaining time with 18^h universal time which corresponds to a conventionalized "sunset" at 0° latitude and 0° longitude.
5. Multiply the difference in hours by 15 to get the difference in longitude. If the product is negative, the position is in the eastern hemisphere, if it is positive the position is in the western hemisphere.
6. Plot the curve that corresponds to the same time of sunset and moonset in a given region and passes through the equator.

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1. *Revolution of the Sun and the Moon and Determination of Lunar Month Statutory Using Computational Techniques*. Cairo: Dar Elfikr AlArabi., p. 86.

2. Ibid, 84.

7. By this we obtain the geometric line passing through all places on the globe: and where the moon can be sighted on the first day of the lunar month.
8. All regions west of this line can sight the moon of sunset if there are no obstacles. However, regions east of this line can only sight the moon at sunset the following day.

Remarks:

- Visual sighting of the new crescent should be in perfect agreement with the data given by the international lunar calendar, or differ at most by one day.
- In some regions, the constant presence of fog and clouds makes sighting very difficult, therefore, refer to computational methods and the date given by the international lunar calendar.
- In higher latitudes where the moon and sun do not set in a 24-hour period, again, use conventions to replace sighting.

Physical Overview of the New Moon Lunar Phase

Ali Kyrala

The definition of the lunar phase known as "new moon" requires that the difference in celestial longitude between the sun and moon be zero. This however does not mean that the lines joining the lunar and solar centers with the earth center coincide in direction. One must recall that while the earth is moving in its (approximately) elliptical orbit about the sun in the ecliptic plane, the moon is traversing an (approximately) elliptical orbit about the earth in its own plane which is inclined about 5 degrees to the ecliptic plane.

The intersection of the lunar orbital plane with the ecliptic plane is called a lunar nodal line and this revolves through 360 degrees during 6,798 days. The lunar elliptical orbit also revolves about the earth within the lunar orbital plane with a perigee period of 3,232 days. During a solar eclipse, the moon is located on its nodal line which also ideally passes through the earth center and solar center. This alignment was the basis of the ancient Saros period of 6,585.33 days between eclipses calculated by the Chaldean astronomers of ancient Babylon.

The new moon phase occurs every month, during which the moon is not generally located on the nodal line or the ecliptic plane, although at the instant defining the simultaneous new moon and solar eclipse an initial assumption will be made that the axes of both earth and moon are orthogonal to the ecliptic taken as coincident with the lunar orbital plane. Although this is not quite correct it will serve to arrive at estimates which will later be modified to partially compensate for the actual axial misalignments. Starting then at the instant of solar eclipse, the motion of the moon in the orbital plane is followed while the earth is rotating 27.3 times as fast as the moon's angular velocity in its orbit.

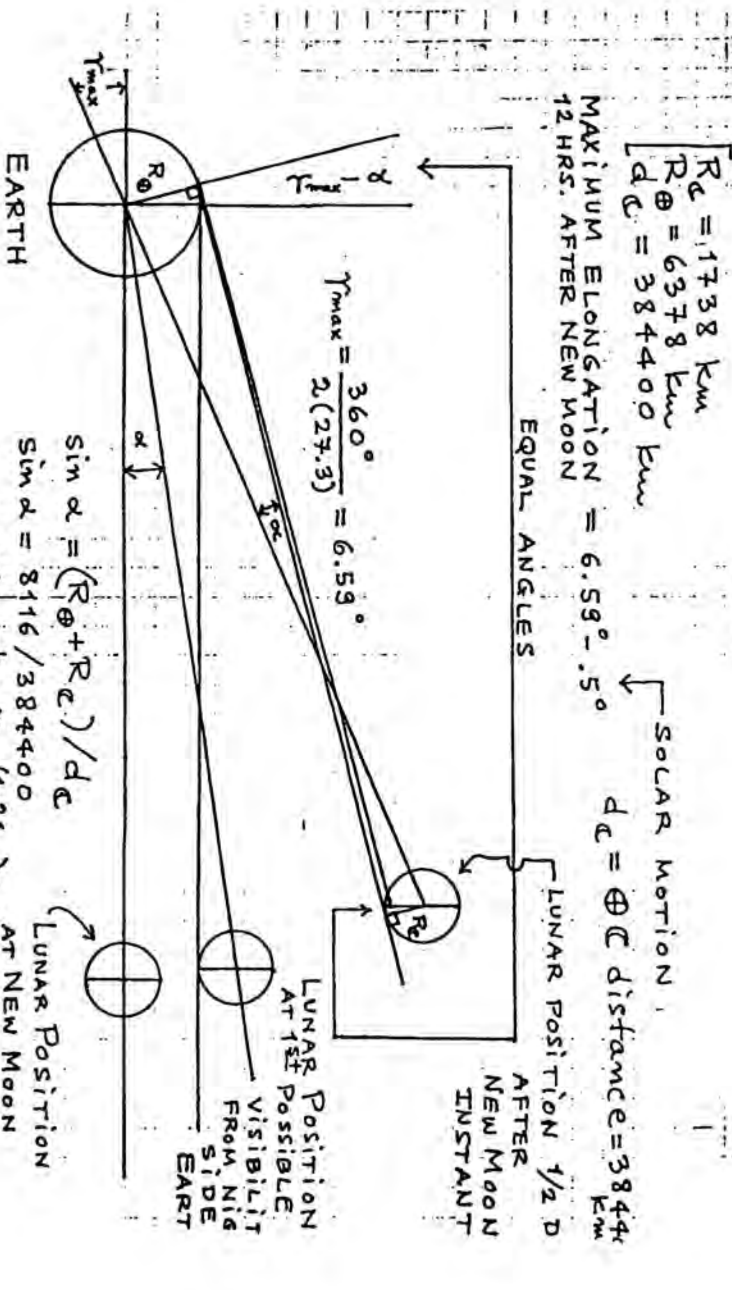
A portion of the moon illuminated by the sun will first become visible at night when the projection on the ecliptic plane of the common tangent line (in the lunar orbital plane) separating earth and moon becomes parallel to the earth-sun line (see Figure 1). This requires about 1.2 degrees of lunar orbit or 2.18 hours. At this time the illuminated section of the moon will first become visible from the night side the earth. Since the moon only travels an average of 13.187 degrees per day and the earth is rotating 27.3 times as fast as the moon is orbiting, the slender crescent will not be visible for more than 25 minutes (6.09x24/360) after sunset before the earth rotates an observer at this location out of view. Even this would only occur under the idealized assumptions (including no refraction) made. Thus it seems that the observational determination of the new moon is of dubious reliability.

The average angular progress of the moon in its orbit is 13.1868 degrees per day (360/27.3). Hence in a halfday after the instant of the new moon it would achieve a maximum elongation of 6.1 degrees, reckoning a half degree of solar motion. Here a day (24 hours) is considered to be centered on the instant of the new moon (see Figure 1). Symmetrical results hold for the 12 hours before and after this instant.

For any lunar elongation within 12 hours of $t = 0$ (the instant of the new moon) the illuminated crescent will only be visible from earth locations on the line determined by A, B and the 2 poles (see Figure 3). The angular relationships are shown in Figure 2 while Figures 3 and 4 are enlarged views. Returning to Figure 3, it is seen that earth locations on the great circle through A and the poles will be instantly rotated out of view of the lunar crescent while locations on the great circle through B and the poles will retain the crescent in view while B is rotated into A. This will require a time equal to 25 minutes. The maximum angular width of the crescent is then given by δ. The intensity of light reflected from it should not exceed a fourteenth of the solar intensity.

The simplest way of accounting for the misalignment of the earth's axis is to regard the misalignment as having the effect of decreasing the effective rotation velocity of the earth by dividing by the cosine of the inclination. Thus cos 25,5 = 0.91704411 so the duration of observation would increase by 9%.

Using maximum elongation (within 1/2 day of $t = 0$) of 6.09 degrees for the line through A, one obtains 28 minutes = 25/cos 23.5°, where $\delta = 1.46 \times 10^{-5}$ degrees for the maximum duration of sighting and maximum angular width of crescent. Again, it seems that the observational determination of the new moon is of dubious reliability.



R☾ = 1738 km
R⊕ = 6378 km
d☾ = 384400 km
MAXIMUM ELONGATION = 6.59° - .5°
12 HRS. AFTER NEW MOON
SOLAR MOTION
d☾ = ⊕☾ distance
EQUAL ANGLES
LUNAR POSITION 1/2 D AFTER NEW MOON INSTANT
γmax − α
γmax = 360° / 2(27.3) = 6.59°
LUNAR POSITION AT 1st POSSIBLE VISIBILITY FROM NIG SIDE EART
LUNAR POSITION AT NEW MOON INSTANT
EARTH
sin α = (R⊕ + R☾)/d☾
sin α = 8116/384400
α = 1.21° ≈ 2h 12m

Figure 1.

Figure 2.

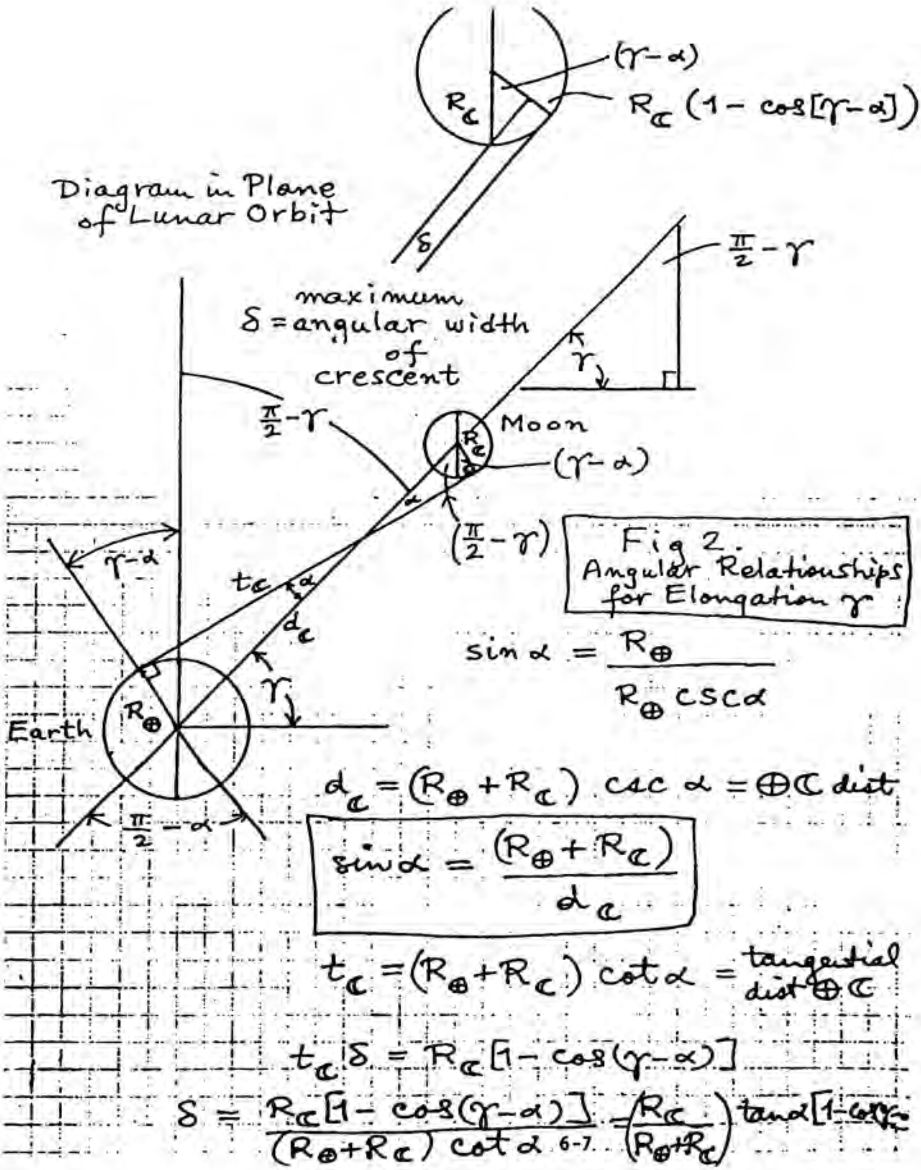

(γ − α)
R☾ (1 − cos[γ − α])
Diagram in Plane of Lunar Orbit
δ
π/2 − γ
maximum δ = angular width of crescent
γ
Moon
(γ − α)
(π/2 − γ)
Fig 2. Angular Relationships for Elongation γ
γ − α
t☾
α
d☾
sin α = R⊕ / R⊕ csc α
Earth
R⊕
π/2 − α
d☾ = (R⊕ + R☾) csc α = ⊕☾ dist
sin α = (R⊕ + R☾) / d☾
t☾ = (R⊕ + R☾) cot α = tangential dist ⊕☾
t☾ δ = R☾[1 − cos(γ − α)]
δ = R☾[1 − cos(γ − α)] / (R⊕ + R☾) cot α
6-7

Figure 3.

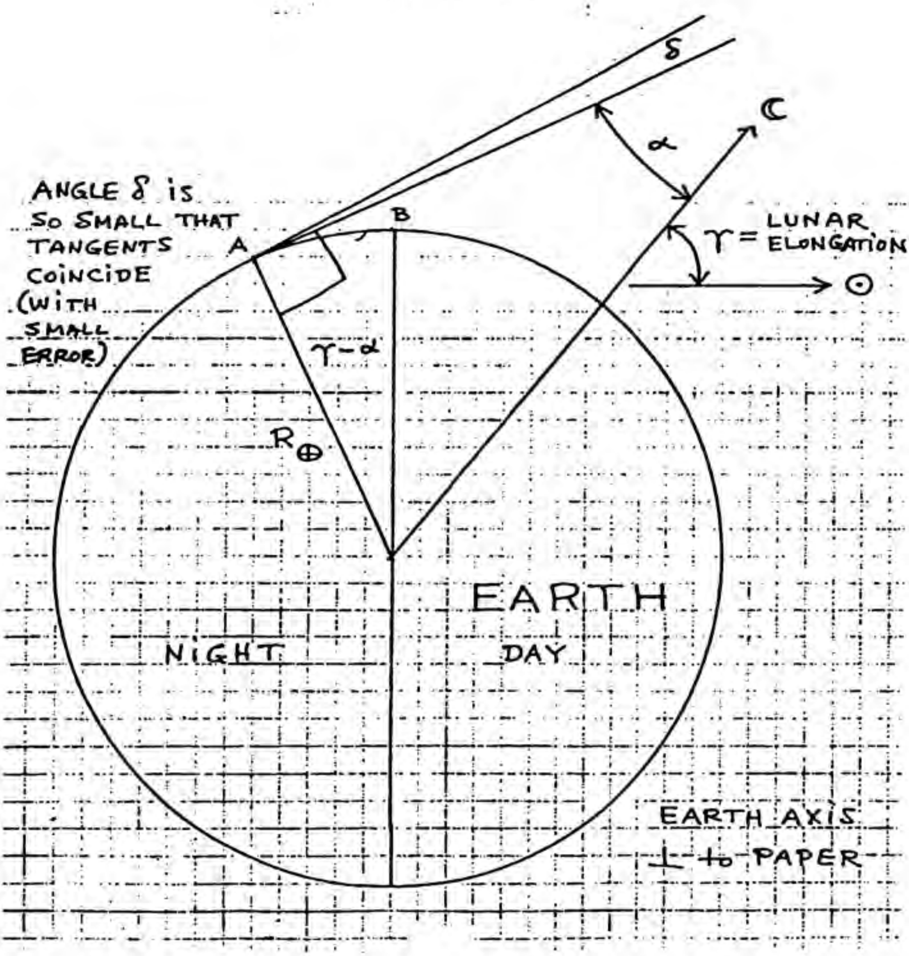
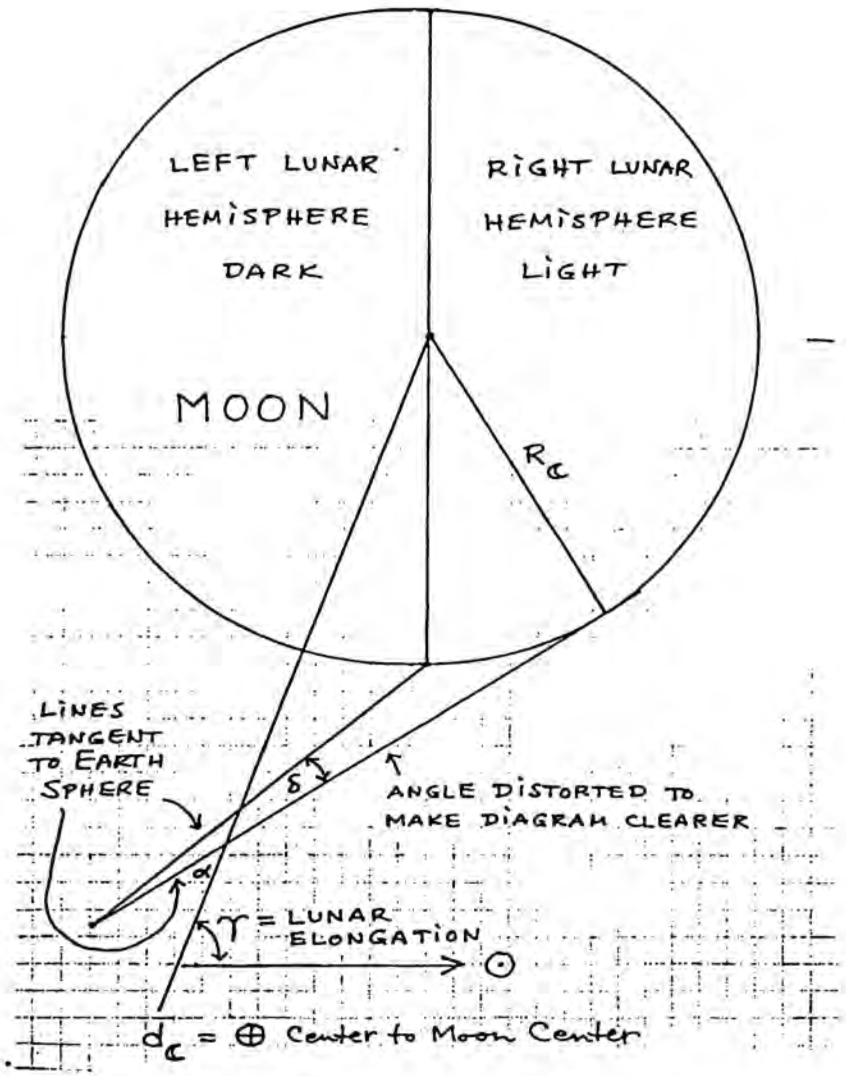

δ
α
☾
ANGLE δ IS SO SMALL THAT TANGENTS COINCIDE (WITH SMALL ERROR)
A
B
γ = LUNAR ELONGATION
⊙
γ−α
R⊕
EARTH
NIGHT
DAY
EARTH AXIS ⊥ to PAPER

Figure 4.


LEFT LUNAR HEMISPHERE DARK
RIGHT LUNAR HEMISPHERE LIGHT
MOON
$R_☾$
LINES TANGENT TO EARTH SPHERE
δ
ANGLE DISTORTED TO MAKE DIAGRAM CLEARER
α
ϒ = LUNAR ELONGATION
☉
$d_☾$ = ⊕ Center to Moon Center

Computer Assisted Calculations to Help Determine the Beginning of Islamic Months

Ahmed S. Massasati

Abstract

Rapid technological advancement, exploration of space, a better understanding of the solar system, and man's ability to make accurate measurements of planetary movements and their relationship to the earth may be of particular interest to Muslims in the context of the Islamic Calendar. The accuracy with which the movement of the earth, the moon and the sun are tracked today may afford Muslims the opportunity to precisely determine the start of Islamic months within the framework of Islamic laws. This may prove helpful in preventing unnecessary conflicts in Islamic communities, and may provide for more brotherhood among Muslims. This manuscript presents a method that will help determine the beginnings of the Islamic months by using a computer to assess the available scientific data and their interpretation in accordance with the guidelines set forth by Qur'an and Sunnah. Also the manuscript will introduce a computer program developed as a part of the Stonehenge project of the University of Missouri at Rolla.

Introduction

While Arabs and other civilizations used a lunar calendar before Islam, 'Umar Ibn al Khattab formally proclaimed the lunar calendar as the Islamic calendar.[1] This aroused a Muslim interest in lunar cycles, resulting in many

1. William Benton, "A Society of Gentlemen in Scotland," *Encyclopaedia Britannica* (Encyclopaedia Britannica, 1971), p. 626.

considerable strides made by early Muslims in the area of Astronomy.[2] However, for the sake of simplicity and practical considerations, and because of inappropriate equipment to precisely determine the movement of the moon, its occurrance—which heralded the beginning of an Islamic month—was left to actual sighting.[3] This is clear from the following hadith:

> Fast upon sighting the new moon and stop your fasting upon seeing the new moon of the next month. (Sahih Al-Bukhari [6])[4]

The beginning of Islamic months have special significance for Muslims because of religious and social activities that follow the appearance of the new moon. Therefore, considerable attention is paid to the determination of the new Islamic month by Muslims all over the world. Laws were designed to prevent confusion and promote harmony in order to establish the beginning of the month. However, despite attempts to unify Islamic communities, confusion often prevails. At the beginning of the months of Ramadan and Shawal, for example, differences in the interpretation of Islamic laws occasionally lead to raging controversies within a community leading to division both locally and regionally. This paper proposes a method to accurately determine the beginning of the lunar month by taking advantage of available scientific data and by developing a computer program.

HISTORICAL PERSPECTIVE

During the Prophet Muhammad's time, people reported the sighting of the moon to him or whoever was in the position of authority. Then, based on the credibility of the witness(es), appropriate decisions were made which were acceptable to the masses. This system worked satisfactorily when communities were small and distances between them long. Each community decided independently when a given Islamic month started. However, with rapid transportation available today, distances have been reduced and advances in telecommunication have virtually linked distant

2. 'Abd al-Halim 'Uways, "Al-Taqwim al-Qamari wa Mushkilatahu," *Asharq al-Awsat*, December 26: 13 (1984).

3. 'Ali al-Jundi, *Qurratu al-'Ayn fi Ramadan wa al-'Idayn* (Matābi' al-Ahram al-Tijariyah, 1969), pp. 49–58.

4. Muhammad Ibn Isma'il Al-Bukhari, *Saḥīḥ Al-Bukhari*, #1722 (Cairo Al-Jumhuriyah al-Arabiyah al-Muttahidah: Al-Majlis al-A'la li al-Shu'wn al-Islamiyah, Lijnat Iḥya' Kutub al-Sunnah, 1971).

communities. This may have aroused the desire of Muslims around the world to unify. As a result, the validity of the conventional method of determining the beginning of the month—actually sighting the new moon—fell into question. Confusion in determining the regional boundaries and how far the boundaries should extend in the event a new moon is sighted in one locality, occasionally leads to divisions among neighboring Muslim communities, particularly at the beginning of Ramadan, and the day of *'Īd al Fiṭr*. The conflicts become more serious when reports of sighting contradict logic and scientific fact. This has necessitated a closer scrutiny of the problems and triggered discussions as to how to take advantage of the scientific facts known today and how to adapt them to suit the needs of Muslims in the light of Islamic guidelines. Islamic teachings strongly emphasize the power of logic and the use of the mind to solve worldly problems. The challenge to the Muslims now is to prove that they are capable of comprehending the new technology and using it for their advancement.

Early Muslims had recognized the possibility of computing the different stages of the moon and decisions based on calculations received preference over that by sighting, if the credibility of the Muslim scholars were well established.[5] However, for the sake of simplicity early Muslim schools of thought did not force such a policy and left the final decision to an appointed regional authority.

MOVEMENT OF THE SUN AND THE MOON

The movement of the sun and the moon has been tracked for a long time but accurate measurement traditionally required a great deal of calculation. With the introduction of computers, it has become possible to integrate a number of equations into one problem. This paper will neither discuss the technical part of the equations nor the methods used to solve them, instead it will introduce a computer program written in FORTRAN to solve the equations,[6] and it will discuss the possibilities of using such programming to find a solution for the problem of determining the beginning of the lunar (Islamic) months.

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5. 'Ali al-Jundi, *Qurratu al-'Ayn fi Ramadan wa al-'Idayn;* and Hamid Al-Jawhari, "Al-Taqwim al-Hijri; Matali' Hilal Flamadan," Majallat al-Hidayah (1986): 20–26.

6. Sun Rise, Sun Set, Moon Rise, Moon Set, computer program distributed by the Muslim Student Association at the University of Missouri Rolla, 1985.

Table 1.

INPUT DATA

RAH	RAM	RASEC	DD	DM	DSEC	PMA	PMD	PARX	IEPH	FYR	FMO	FDY	FHR	FMN	FSC	DT	FINC	NOINC	FJD
0.	0.	.000	0.	0.	.000	.0000	.000	.0000	1980	1999.	1.	1.	0.	0.	.0	54.20	1.	30	.0000

2451179.50000 = BEGINNING JD. JMP= 4, IDT= 0, IET= 0, ISKIP= 0 PRAYER TIMING & MOON SIGHTING VER I

LATTITUDE AND LONGITUDE OF STATION FOR SUNRISE-SET & OPTIONAL STD TIME

LATTITUDE D M S	LONGITUDE D M S	TIME ZONE H	TWILIGHT ANGLE D	ALT D
21. 27 .00 N	-39 45. .00 W	3.0	-18.	-.8333

DAY	FAJR H M	SUN RISE H M	ZUHR H M S	ASER H M	MAGHRIB H M	ISHA H M	SR AZ 0 '	SS AZ 0 '	NOON ALT DEG.
1999 JANUARY									
1 FRI	5 39.5	6 58.8	12 24 20.5	15 28.9	17 50.0	19 9.2	114 30.4	245 31.9	45.55
2 SAT	5 39.9	6 59.1	12 24 48.6	15 29.5	17 50.6	19 9.8	114 25.1	245 37.5	45.63
3 SUN	5 40.3	6 59.4	12 25 16.4	15 30.1	17 51.2	19 10.4	114 19.2	245 43.6	45.72
4 MON	5 40.6	6 59.7	12 25 43.9	15 30.7	17 51.9	19 10.9	114 12.8	245 50.2	45.82
5 TUE	5 40.9	6 59.9	12 26 10.9	15 31.3	17 52.5	19 11.5	114 6.0	245 57.3	45.93
6 WED	5 41.2	7 .2	12 26 37.5	15 31.9	17 53.2	19 12.1	113 58.6	246 4.9	46.04
7 THU	5 41.5	7 .4	12 27 3.7	15 32.5	17 53.9	19 12.7	113 50.8	246 12.9	46.16
8 FRI	5 41.8	7 .6	12 27 29.4	15 33.1	17 54.5	19 13.3	113 42.5	246 21.4	46.29
9 SAT	5 42.0	7 .8	12 27 54.7	15 33.8	17 55.2	19 13.9	113 33.7	246 30.4	46.43
10 SUN	5 42.3	7 .9	12 28 19.4	15 34.4	17 55.9	19 14.5	113 24.5	246 39.9	46.57
11 MON	5 42.5	7 1.0	12 28 43.5	15 35.0	17 56.5	19 15.1	113 14.8	246 49.8	46.72
12 TUE	5 42.7	7 1.2	12 29 7.2	15 35.6	17 57.2	19 15.7	113 4.6	247 .2	46.88
13 WED	5 42.9	7 1.2	12 29 30.2	15 36.2	17 57.9	19 16.3	112 54.0	247 11.0	47.05
14 THU	5 43.0	7 1.3	12 29 52.6	15 36.9	17 58.6	19 16.9	112 42.9	247 22.3	47.22
15 FRI	5 43.2	7 1.4	12 30 14.4	15 37.5	17 59.3	19 17.5	112 31.4	247 34.1	47.40
16 SAT	5 43.3	7 1.4	12 30 35.5	15 38.1	17 60.0	19 18.1	112 19.4	247 46.2	47.58
17 SUN	5 43.4	7 1.4	12 30 56.0	15 38.7	18 .6	19 18.6	112 7.0	247 58.8	47.77
18 MON	5 43.4	7 1.4	12 31 15.7	15 39.3	18 1.3	19 19.2	111 54.2	248 11.9	47.97
19 TUE	5 43.5	7 1.3	12 31 34.7	15 39.9	18 2.0	19 19.8	111 40.9	248 25.3	48.18
20 WED	5 43.5	7 1.3	12 31 53.0	15 40.5	18 2.7	19 20.4	111 27.3	248 39.2	48.39
21 THU	5 43.6	7 1.2	12 32 10.5	15 41.1	18 3.4	19 21.0	111 13.2	248 53.4	48.61
22 FRI	5 43.6	7 1.1	12 32 27.3	15 41.6	18 4.0	19 21.5	110 58.7	249 8.1	48.83
23 SAT	5 43.5	7 .9	12 32 43.3	15 42.2	18 4.7	19 22.1	110 43.9	249 23.1	49.06
24 SUN	5 43.5	7 .8	12 32 58.5	15 42.8	18 5.4	19 22.6	110 28.6	249 38.6	49.30
25 MON	5 43.4	7 .6	12 33 12.8	15 43.3	18 6.0	19 23.2	110 13.0	249 54.4	49.54
26 TUE	5 43.3	7 .4	12 33 26.4	15 43.9	18 6.7	19 23.8	109 57.0	250 10.6	49.79
27 WED	5 43.2	7 .2	12 33 39.1	15 44.4	18 7.4	19 24.3	109 40.6	250 27.1	50.04
28 THU	5 43.1	6 59.9	12 33 51.0	15 44.9	18 8.0	19 24.8	109 23.8	250 44.1	50.30
29 FRI	5 42.9	6 59.6	12 34 2.1	15 45.4	18 8.6	19 25.4	109 6.7	251 1.3	50.56
30 SAT	5 42.7	6 59.4	12 34 12.4	15 45.9	18 9.3	19 25.9	108 49.3	251 18.9	50.83
27 WED	5 43.2	7 .2	12 33 39.1	15 44.4	18 7.4	19 24.3	109 40.6	250 27.1	50.04
28 THU	5 43.1	6 59.9	12 33 51.0	15 44.9	18 8.0	19 24.8	109 23.8	250 44.1	50.30
29 FRI	5 42.9	6 59.6	12 34 2.1	15 45.4	18 8.6	19 25.4	109 6.7	251 1.3	50.56
30 SAT	5 42.7	6 59.4	12 34 12.4	15 45.9	18 9.3	19 25.9	108 49.3	251 18.9	50.83
31 SUN	5 42.5	6 59.0	12 34 21.9	15 46.4	18 9.9	19 26.4	108 31.5	251 36.9	51.11

*** INDICATES NO PHENOMENON

The computer program provides information in two sets. One of them is for the calculation of the movements of the sun (see Table 1) and the other for the calculation of the movements of the moon (see Table 2). The user

Table 2.

INPUT DATA:

RAH RAM RASEC DD DM DSEC PMA PMD PARX IEPH FYR FMO FDY FHR FMN FSC DT FINC NOINC FJD

0. 0. .000 0. 0. .000 .0000 .000 .0000 1980 1999. 1. 1. 0. 0. .0 54.20 1. 30 .0000

2451179.50000 = BEGINNING JD. JMP= 4, IDT= 0, IET= 0, ISKIP= 0 PRAYER TIMING & MOON SIGHTING VER 1

LATITUDE AND LONGITUDE OF STATION FOR SUNRISE-SET & OPTIONAL STD. TIME

LATTITUDE D M S	LONGITUDE D M S	TIME ZONE H
21. 27. .00 N	-39. 45. .00 W	3.0

	DAY	MOON RISE H M	MOON SET H M	LENGTH SHINE H M	MOON SOUTH H M S	MOON AZIMUTH RISE 0 '	MOON AZIMUTH SET 0 '	MERD. ALT DEG.	---THE MOON AGES--- AT RIS DAYS	AT MER DAYS	AT SET DAYS
	1999 JANUARY										
F	1 FRI	17 22.3	5 56.7	13 32.2	** 0 .0	69 3.6	290 32.6	******	13.65	****	13.18
	2 SAT	18 22.1	6 57.4	13 35.1	0 10 2.5	69 18.2	290 59.7	88.08	14.69	13.9	14.22
	3 SUN	19 22.2	7 54.2	13 32.1	1 9 11.8	70 57.6	289 57.8	87.48	15.74	15.0	15.26
	4 MON	20 21.0	8 46.1	13 23.9	2 5 47.0	73 46.5	287 39.4	85.60	16.78	16.0	16.29
	5 TUE	21 17.6	9 33.2	13 12.1	2 58 60.0	77 25.6	284 22.7	82.72	17.82	17.1	17.33
	6 WED	22 11.6	10 15.9	12 58.4	3 48 45.6	81 36.5	280 26.6	79.13	18.85	18.1	18.36
	7 THU	23 3.4	10 55.5	12 43.9	4 35 30.5	86 3.1	276 8.3	75.12	19.89	19.1	19.38
	8 FRI	23 53.6	11 32.9	12 29.5	5 19 58.9	90 33.5	271 40.8	70.91	20.92	20.2	20.41
	9 SAT	***	.0	12 9.1	12 15.6	6 3 1.8	267 14.8	66.69	20.93	21.2	21.43
	10 SUN	0 42.7	12 45.2	12 2.5	6 45 30.6	94 57.6	262 58.9	62.60	21.96	22.2	22.46
	11 MON	1 31.6	13 22.0	11 50.4	7 28 13.6	99 7.2	259 1.2	58.77	22.99	23.2	23.49
A	12 TUE	2 20.8	14 0.4	11 39.6	8 11 53.7	102 54.0	255 29.8	55.33	24.03	24.3	24.51
	13 WED	3 10.8	14 41.3	11 30.5	8 57 5.3	106 9.3	252 33.8	52.43	25.06	25.3	25.54
	14 THU	4 1.6	15 25.2	11 23.6	9 44 9.7	108 43.1	250 23.1	50.21	26.10	26.3	26.57
	15 FRI	4 53.1	16 12.5	11 19.3	10 33 10.4	110 25.4	249 7.8	48.82	27.13	27.4	27.60
	16 SAT	5 44.7	17 3.1	11 18.4	11 23 50.4	111 6.8	248 56.5	48.41	28.17	28.4	28.64
	17 SUN	6 35.6	17 56.6	11 21.0	12 15 35.2	110 40.7	249 54.5	49.06	29.20	29.4	29.68
N	18 MON	7 25.1	18 52.2	11 27.1	13 7 42.1	109 5.1	252 1.7	50.79	.53	.8	1.01
	19 TUE	8 12.6	19 49.1	11 36.5	13 59 32.7	106 23.6	255 12.6	53.54	1.56	1.8	2.05
	20 WED	8 58.2	20 46.5	11 48.4	14 50 44.8	102 44.7	259 16.5	57.16	2.59	2.8	3.09
	21 THU	9 42.0	21 44.2	12 2.2	15 41 17.2	98 21.0	263 59.4	61.46	3.62	3.9	4.13
	22 FRI	10 24.7	22 42.1	12 17.4	16 31 29.2	93 27.1	269 5.4	66.18	4.65	4.9	5.17
	23 SAT	11 7.3	23 40.5	12 33.2	17 21 54.6	88 19.2	274 17.1	71.07	5.68	5.9	6.21
	24 SUN	11 50.6	***	***	18 13 14.7	83 14.5	***	75.84	6.71	7.0	7.25
	25 MON	12 35.7	0 39.6	12 49.0	19 6 7.5	78 30.7	279 16.3	80.19	7.74	8.0	7.25
	26 TUE	13 23.5	1 40.0	13 4.3	20 0 56.8	74 26.7	283 44.1	83.82	8.78	9.1	8.29
P	27 WED	14 14.7	2 41.3	13 17.7	20 57 39.6	71 20.9	287 21.1	86.45	9.81	10.1	9.33
	28 THU	15 9.3	3 42.6	13 27.9	21 55 38.6	69 29.4	289 49.5	87.85	10.85	11.1	10.37
	29 FRI	16 6.6	4 42.7	13 33.5	22 53 45.9	69 2.1	290 56.3	87.91	11.89	12.2	11.42
	30 SAT	17 5.6	5 40.2	13 33.5	23 50 41.7	70 .1	290 36.7	86.66	12.93	13.2	12.46
F	31 SUN	18 4.6	6 33.7	13 28.1	**	72 14.9	288 55.9	******	13.97	****	13.49

*** INDICATES NO PHENOMENON, N = NEW MOON, F = FULL, P = MOON NEAR PERIGEE, A = NEAR APOGEE, B = MOON BELOW HORIZON NEW MOON OCCURS ON DAY 17 AT 18.7 HOURS

has to select the appropriate table in order to make the best use of the provided information.

Table 3.
Exact Location of Sun and Moon and the Difference in Their Setting Time on January 17, 18, and 19, 1999

Date of Observation	January 17	January 18	January 19
Location from North			
Location of Sunset*	247 58.8	248 11.9	248 25.3'
Location of Moonset*	249 54.5	252 1.7	255 12.6'
The Difference	1 55.3	3 49.8	6 47.3
Time of Sunset**	18 0.6	18 1.3	18 2.0
Time of Moonset**	17 56.6	18 52.2	19 49.1
The Different	-0 4.0	0 50.9	1 47.1
Moon's Age at Set (in Days)	29.68	1.01	2.05

* Locations are given in degrees and minutes starting from true North.
** Time is given in hours and minutes for local time (Makkah, Saudi Arabia).

THE SUN AND MOON TABLES

The results shown in Table 1 provide basic information about the movement of the sun. This table can be used for calculating prayer times as well as for calculating the location of the sun at sunrise, noon, and sunset for a given location on earth. Makkah has been chosen as the example in Table 1. The results shown in Table 2 provide similar information for the moon.

For most locations on earth the best place to locate the new moon is near where the sun sets; and the best time to sight the new moon is at sunset. Therefore, information about the location of the sun and the difference between its location and that of the moon's can provide the observer with the best predicted location for sighting of the new moon. The difference between the time of the sunset and the time of the moonset can give the observer an idea about the time available for sighting the moon. The program also gives the day when the new moon starts so that one does not have to look through all the days; such attempts could be limited to only one day before or after the expected appearance of new moon. The example given in Table 3 is for the days of January 17, 18, and 19, 1999.

In order to make use of the results of Table 3, it should be realized that if the moon sets before the sun, the new moon cannot be sighted because the light of the sun will make sighting impossible. Therefore, the new moon of Shawwal cannot be sighted on January 17 because on this day the moon sets 5 minutes before the sun. On January 18, the moon sets 51 minutes after the sun, thus making it probable to sight the moon. From this example, the first day of Shawwal will be January 19, 1999. In addition to this information, the program also gives an idea about the age of the moon at the time of observation. This information is given for three times of the day.

PROPOSED GENERAL SOLUTION

If simplicity and science are acceptable, the following two general solutions could be proposed by employing the previous information:

The first solution is, taking Makkah as a reference point, calculate the beginning of the Islamic month astronomically in advance and let all Muslims follow that, regardless of location or political system. This approach is more logical for the pilgrimage to Makkah, for Hajj is an international Islamic event even though appearance of the moon may be considered a regional matter.

The second solution responds to the insistence of local sighting of the moon. The program offers valuable and precise information about the time of the new moon, regardless of the observer's location. In the example above, the new moon began on January 17 at 16.3 Hr. (Table 2). If the scientific solution is accepted as the basis for decision making, then the new moon is decided with relevance to the astronomical new moon, regardless of the observer's location. This means that once the time of the new moon is decided astronomically, each country will start the month of Ramadan according to their time zone or that of the community's political center. For example, if the sun sets at 6 o'clock for a given observer in a given time zone, while the new moon started before six for that observer, then Shawwal is the next day regardless of whether the observer saw the new moon or not. If the new moon started after six then Shawwal begins the day after. With such a system the time and location of the astronomical new moon can be announced in advance, benefiting Muslims all over the world.

CONCLUSION

To continue ignoring the scientific facts is in no way Islamic. Scientific facts should be accepted and adapted within the Islamic context. In the Qur'an Allah says:

> If ye realize this not, ask of those who possess the message. (*al Nahl*:43)

Also, when the Prophet Muhammad was asked about a method of polinating the date palms to increase their yield, he responded by saying: "You know better about your worldly problems."[7]

The general meaning of the *ayah* and the *hadith* is that in worldly issues, it is up to Muslims to evaluate their circumstances and make decisions. Decisions on the new moon should be given to Muslim scientists who possess the knowledge and wisdom to help answer the question. It is time for Muslim scholars and governments to recognize the fact that such decisions are worldly issues and can be solved scientifically, keeping in mind the guidelines set forth by the Qur'an and Sunnah.

Computer programs that calculate the movement of the sun and moon have been made by several Muslim and non-Muslim scientists and can be purchased [or downloaded from the Internet, Ed., 1998].

ACKNOWLEDGMENTS

The author would like to acknowledge the support and guidance of Professor Joseph H. Senne from the University of Rolla-Missouri in supervising the computer project. Special thanks to brother Dr. Fazl Mohammad who helped with his editing and gave valuable advice. Also thanks to all the brothers of MSA-UMR who took the responsibility of distributing the program and rewriting it to fit the IBM PC computer.

7. Muhammad Ibn Yazid Ibn Majah, *Sunan al-Hajiz Abi 'Abd Allah Muhammad ibn Yazid al-Qazwini ibn Majah, 15 Kitab Al-Ruhun*, #2471, edited by Muhammad Fu'ad 'Abd al-Baqi (Dar Iḥya' al-Turath al-'Arabi, 1975), p. 825.

A Study on Establishing an International Lunar Calendar

Fakhreddine Karray

Introduction

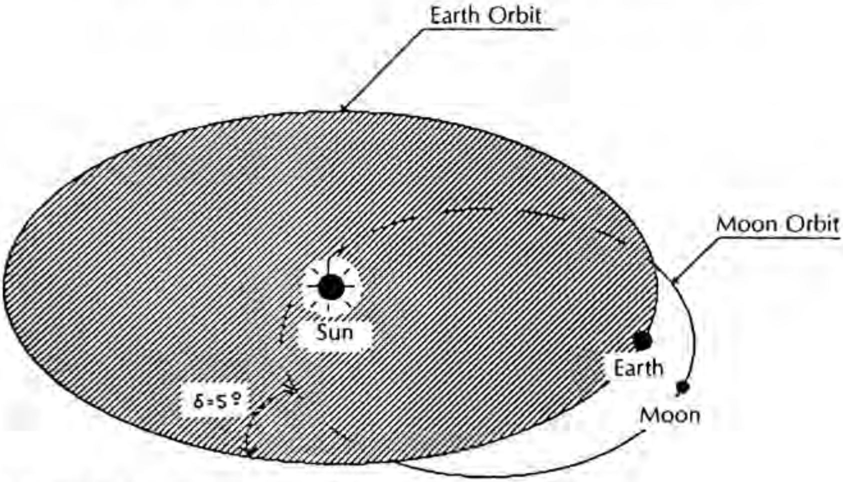
For a long time, Muslim scientists and *'ulama* from all over the world have been studying the possibility of setting a lunar calendar compatible with the principles of the Shari'ah. Many attempts were made in this direction, but none of them was taken seriously by the whole Muslim community. The most difficult thing about establishing such a lunar calendar, which is based on both the astronomy of position and its computational techniques and the constraints of the Qur'an and Sunnah, is not the technical difficulties engendered by astronomy but rather the differences that exist among people in understanding the definition of the "beginning" of the lunar month.

The technical aspects of the problem and the computational techniques will not be my focus. Instead, I will try to define the problem by describing its physical aspects, underlining the sources of confusion among the Muslim community around the world, and finally, highlighting a set of approaches that can help establish an important step toward an international lunar calendar.

Preliminaries

The moon is known to be the nearest celestial object to the earth (average distance 384,000 km), and since the earth is of a bigger mass it is expected that the moon follows an elliptical orbit around our globe (see Figure 1). But this is not exactly true. In fact, the orbit of the moon is a moving ellipse, which each month changes its position around what is

Moon's Position with Respect to the Earth and the Sun



δ : Inclination between the ecliptic and the moon orbit

Note: The drawing scales of the lunar and earth orbits are very unrealistic.

Figure 1.

called "line of nodes." However, this ellipse keeps a constant inclination angle with respect to the orbit of the earth (ecliptic, 5°8'). The complications in the moon orbit described above are due essentially to the secondary effect of the sun's gravitation. This problem is well known among astronomers as the "three body problem." In fact, this problem becomes even more complicated if we include the effect of planetary gravitation.

At the beginning of this century an acceptable solution to the problem was found in the form of parametric series. By means of today's computers we can reach a very high degree of precision in the calculation of certain astronomical events (conjunctions, eclipses, etc). In brief, based on what was stated, we can conclude that the computation of the orbital elements of the moon is not an easy task. Nevertheless, it can be done by some experts with very high accuracy, and such calculation can be used in defining a calendar compatible with the principles of Islam.

The Lunar Calendar and the Phases of the Moon

Many civilizations throughout the ages have adopted, for simplicity, the lunar month as the basis from which to measure time. For them the day was the difference in time between sunrise and sunset, and the month was the difference in time between two identical moon phases.

Since the very beginning of the Muslim civilization, the same convention was adopted. For the *ummah*, the lunar month begins with the sighting of the new crescent, and the year is divided into twelve lunar months. Before going any further let us describe what happens to the moon's appearance (the phases of the moon) during its rotation around the earth. A good description of this phenomenon was given by Chapman as follows (see Figure 2):[1]

> If we watch the moon regularly, we can easily discover that it changes its apparent shape from night to night; that is, it goes through a series of phases. Let's begin a series of nightly observations of the moon on an early evening when we see it as a very thin crescent, not far from the spot where the sun has just set. When we first notice the thin crescent, the red glow of sunset probably still colors the western sky. As it becomes darker, the entire circular disk of the moon is illuminated with a faint, ruddy glow. This is known as the "old moon in the new moon's arms." The moon then sets soon after the sun. The next evening the moon will appear higher in the sky and will be a thicker crescent. It sets 50 minutes later than it did the night before. The moon moves its own diameter (0.5°) eastward among the stars each hour; so it covers 13° per day, and as a result rises and sets about 50 minutes later each day.
>
> After we have been watching the moon for a week, it will be at the phase called first quarter. Half the moon's face toward the earth is illuminated. At sunset, the moon is roughly due south, near its highest point in its daily path across the sky. During the following week, the moon passes through the gibbous phase as the face toward the earth becomes more and more fully illuminated. At the end of the second week after we first saw the crescent, the moon is full. The full moon rises at sunset, and is in the sky for the entire night. On such nights the intense light of the full moon makes the sky so bright that all but the brightest stars are hidden in the glow.

1. R. Chapman, *Discovering Astronomy* (Freeman and Company, 1978).

For the next two weeks, the moon goes through the phase inverse: full, gibbous, third quarter, and crescent, until after four weeks (actually 29 1/2 days) the moon is new. New moon is the opposite of full moon: the new moon is completely dark. During these two weeks the moon still continues to rise later and later each night. The third-quarter moon rises around midnight, six hours before the sun, and the thin crescent moon rises just before the sun on the eastern horizon.

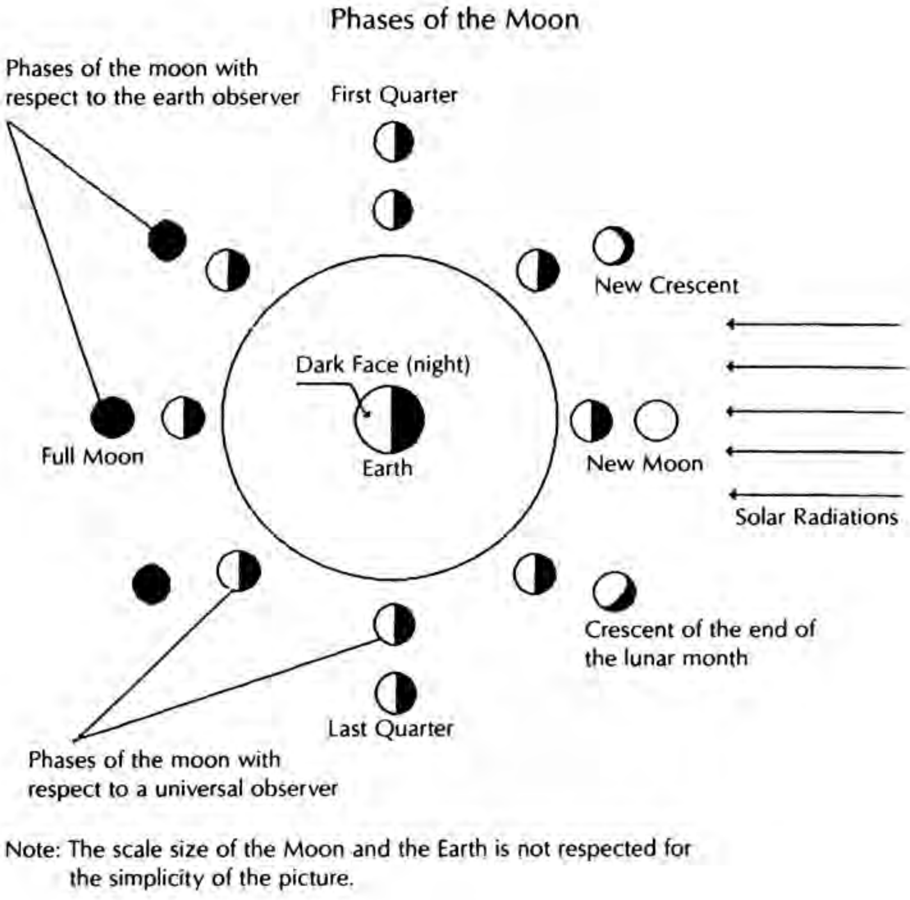


Figure 2.

Sources of Confusion and Controversial Reports

After the appearance of the new ephemeries and diaries that gave the dates of conjunctions and many other periodic astronomical events, many people thought that the problem of determining the Muslim lunar calendar would be solved; instead, a great deal of confusion among people and countries took place and, hence, so many controversies were created. These controversies are mainly due to the lack of sighting coordination among Muslim countries and the adoption of different criteria for determining the new lunar month. In order to investigate some aspects of this problem, I corresponded with many people around the Muslim world, and I discussed the matter with officials during Islamic meetings. Surprisingly, I found that the bases of announcement among many Muslim countries are very different. These differences can reach as many as four solar days. The major adopted criteria are summarized below.

- *Conjunction before midnight:* If the conjunction takes place before midnight local time (even a few minutes earlier), then the following solar day is considered the beginning of the new lunar month.
- *Conjunction before sunset:* If the conjunction takes place just before local sunset (moonset after sunset), then the following solar day is considered the beginning of the lunar month even though there is no sighting of the new crescent.
- *Empirical calendar:* Some Islamic countries decide on the beginning of the lunar month by using some rough empirical methods. These methods can give, with some degree of accuracy, the solar day corresponding to the new lunar month.
- *Improper criterion of the first visibility:* This basis was adopted by some Islamic countries according to the final statements of some Islamic conferences (Istanbul, Cairo). Even though this criterion can give a close approximation to the beginning of the new lunar month, it uses some improper estimations which can cause some errors.

After examining these different criteria, we can conclude that the difference in announcing the beginning of the lunar month can be as many as one to four days. As a matter of fact, this unjustifiable difference reached four days in the Ramadan of 1985. Consequently, confusion and controversies take place instead of unity and harmony during such holy events. Such a situation is no longer acceptable and serious efforts must be taken by scientists and religious leaders to prevent future chaos.

Some Suggestions and a Set of Approaches

For a very long time it has been made clear by the *fuqaha* that according to the Qur'an and Sunnah the month begins only if the new crescent moon is sighted. Nowadays, we enjoy the magnificent development of science in all its fields, especially in astronomy. The idea here is to use this advantage to build a lunar calendar compatible with our religious principles. This is not an easy task, as some people believe, since the problem of compatibility requires some experimental results. Nowadays, it is indisputable that the date of the moon's conjunction and other orbital parameters can be computed with very high accuracy. However, this does not answer our main question in locating the place where the first visibility of the new moon is possible. It is, therefore, necessary to use experimental facts such as the minimum constraints of observability of the new moon in a place where there is sunset. During the Istanbul Conference in 1978, studies were carried out by several experts, and the following statement was issued :

> There is no possible moon sighting unless three conditions are met:
>
> 1. The difference of elongation between the sun and the moon should not be less than 8°.
> 2. The height of the moon above the local horizon should not be less than 5°.
> 3. The two previous constraints must happen in a place just after sunset.

These conditions were based essentially on some experimental facts and studies done by experts in this matter (e.g., the Danjon Limit).

Although the Istanbul Conference provided a dynamic start to many research projects concerned with this matter, many Muslim countries chose not to follow its suggestions. In 1982, thorough investigations based on some experimental aspects and available data were carried out by Karray and Choras and led to the following conclusions:

- The criterion of the 8° difference in the elongation between the sun and the moon is not very proper, and adding 2° or 3° would give more accurate results.
- The 5° height of the moon above the horizon should not be generalized for all geographic latitudes. Hence, some corrections are required. Also, this constraint of lower limit visibility is corrupted by uncertainties especially in the lower latitudes and it should be taken into account, since it implies a wide range of uncertainties around the longitudes of those regions.

A major point has to be mentioned here concerning the proper meaning of sighting. If the definition of moon sighting is determined to be other than with the naked eye (requiring a *fatwa* from the '*ulama*), then we can come up with a new solution to the problem. This suggestion was proposed in 1985 (Karray) and lengthy discussions with Muslim scientists were carried out during subsequent conferences.

Today, by means of radar we can locate the position of the moon with very high accuracy while it is still impossible to sight with the naked eye. The only condition required to detect the new moon by radar is that the observation take place just after the conjunction of the moon at local sunset. This new procedure should be studied further. Taking this suggestion one step further would be to built a radar network at the mid-latitudes. By virtue of this meaning of sighting, the lunar month can be announced one day earlier than the naked eye's first observation.

Obviously, the problem of the moon's first sighting cannot be solved unless a lot of effort toward deep understanding of the facts takes place.

Conclusion

Concerted reflection by scientific and religious communities is required to solve some of the problems and eliminate the spread of controversies which occur at every holy event. Furthermore, an official scientific committee should be formed as soon as possible in order to coordinate the efforts of Muslim scientists around the world in solving this problem. Also, a bridge of understanding between this committee and the '*ulama* should be established so that a realistic and final solution to the problem is reached.

CALCULATING AND OBSERVING THE CRESCENT MOON

LeRoy E. Doggett & P. Kenneth Seidelmann

The Lunar Ephemeris

The astronomical new moon is defined to occur when the geocentric apparent longitudes of the sun and moon are exactly equal. Although the average interval between new moons is approximately 29.53 days, any particular interval may vary from this average by up to about a quarter day. Thus an accurate calculation of the moon's phases requires accurate theories for the motions of the sun and moon. We can now calculate the position of the moon to better than 0.001 arc-second for dates in the current era. While this accuracy is required for scientific studies of the dynamics of the earth/moon system, it is not needed for calculating lunar phases. In practice, we calculate time of phases to an accuracy of one minute for several decades into the future.[1]

The Crescent Moon—Observation and Theory

Sightings of young lunar crescents are not only the basis of lunar calendars, they are a source of friendly competition among astronomers. While there have been a number of authentic sightings of the moon at ages of less than 20 hours, sightings at less than 15 hours are extremely rare.[2] Such

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1. B. L. Morrison, "Phases of the Moon 1960-2003," U.S. Naval Observatory Circular No. 119 (Nautical Almanac Office, U. S. Naval Observatory, 1968); R. L. Schmidt, "Phases of the Moon 2000-2049," U. S. Naval Observatory Circular No. 169 (Nautical Almanac Office, U. S. Naval Observatory, 1986).

2. J. Ashbrook, "Observing very thin lunar crescents," *The Astronomical Scrapbook* (Cambridge, MA: Sky Publishing, 1984).

sightings require optimal observing conditions and an experienced observer with keen eyesight.

Precise prediction of the time and location of first sighting is hampered by observational difficulties. Some of the relevant factors, such as the age of the moon, the elongation of the moon from the sun, and the position of the moon in its orbit, can be calculated accurately. Other factors depend on local observing conditions and may not be known in advance. Horizons are seldom perfectly flat, and the transparency of the air, even in good weather, depends on location, time of day and season. Ultimately, a successful sighting requires a perceptive and knowledgeable observer. These problems, of course, have not deterred astronomers from developing prediction models. A book by Ilyas offers a good survey and an extensive bibliography.[3]

Efforts by Bruin,[4] Ilyas,[5] and Schaefer[6] have resulted in new interest in the problems of calculating first visibility. Perhaps Ilyas's greatest contribution has been to shift concern away from estimating the minimum age or minimum altitude at which the crescent can be observed at a given location. Instead, taking a global perspective, he defines a curve on the earth's surface that determines the limit of first visibility as a function of longitude and latitude. He calls the curve the "international lunar date line" (ILDL). This line is the center of a zone of longitude in which the ability to sight the crescent depends critically on atmospheric conditions and the sensitivity of the observer. Locations west of this zone should see the crescent, provided weather is favorable. Locations east of the zone will not see the crescent until the next evening. Ilyas estimates the width of this zone to be about 30° east and west of the ILDL. Schaefer has adopted Ilyas's concept of the ILDL, but he has developed a more sophisticated theoretical model. A critical parameter in Schaefer's model is the visual extinction coefficient coefficient k_v, which can be measured by astronomical observations.

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

4. Bruin, F. 1977. "The First Visibility of the Lunar Crescent." *Vistas in Astronomy* 21: 331–358.

5. Ilyas, *A Modern Guide to Astronomical Calculations of Islamic Calendar, Times & Qibla.*

6. B. E. Schaefer, *Proceedings of the Lunar Calendar Conference* (Herndon: IIIT, 1988).

Incorporated in this model are data from new observations that Schaefer has made at a variety of locations.

The astronomical new moon of April 28, 1987 provided an opportunity for testing some of the prediction models. At the time of sunset on the east coast of the United States, the moon was about 22 hours old. By the time of sunset on the west coast, it was more than 25 hours old. The international lunar date line of Ilyas[7] predicted visibility for forty-eight contiguous states of the United States. Schaefer's ILDL[8] is based on an extinction value of $k_v = 0.3$. A traditional reference standard was provided by H. M. Nautical Almanac Office of the United Kingdom.[9] They determined the longitude and latitude at which the apparent altitude of the moon at sunset is 10°, and the sun and moon are at the same azimuth.[10] According to this, first sighting should occur at longitude 86°15'.4 west and latitude 33°30'.1 north. This is in the state of Alabama in the southeastern United States. Figure 1 shows the predictions from the models mentioned above. To illustrate the critical role played by atmospheric extinction, curves from Schaefer's model are shown for $k_v = 0.2$ and 0.4, where 0.2 is remarkably good and 0.4 is very bad transparency.

Observing Program

We tried to establish an observing program with a minimum of time, expense, and effort. Our goal was to create a good distribution of observers across the United States. A week before the event we began calling friends and colleagues to solicit their assistance. Observers were given the times of sunset and moonset, and the altitude and azimuth of the moon at sunset for their locations. They were asked to report whether the moon was sighted and the time of such a sighting. Environmental information, such as cloud cover was also requested. Although we began with about twenty observers on our list, word gradually spread and we picked up a much larger collec-

7. Ilyas, *A Modern Guide to Astronomical Calculations of Islamic Calendar, Times & Qibla.*

8. Schaefer, *Proceedings of the Lunar Calendar Conference.*

9. B. D. Yallop, "Earliest Sighting of the New Moon in 1987," RGO Astronomical Information Sheet, No. 50 (H. M. Nautical Almanac Office, Royal Greenwich Observatory, 1987).

10. B. D. Yallop, private communication. This criterion is based on the results of Bruin.

tion of observers than we had anticipated. In some cases, astronomy instructors took their classes out for an evening of practical observing. At one observatory, 75 visitors attending a star party were pressed into service. Figure 2 shows the locations of the observing sites. Table 1 lists these locations with times of sunset and moonset, and the position of the moon. In Table 2 we list results of the observations. Since some of our information came second hand, these tables may be incomplete and not entirely accurate. At the present time we know of about 180 observers at 46 localities.

The Observations

As any astronomer can tell you, the earth is shrouded in clouds. Figure 3 is a satellite photo of North America, taken at 5:31 p.m., eastern daylight time, on April 28. Where heavy cloud cover was not totally obstructing observations, haze vapor trails and thin clouds seemed to cause difficulties. Many of the observers reported some atmospheric obstructions, with the result that there were remarkably few sightings, considering the number of observing sites. In fact, the northeastern states had a snowstorm that evening, and much of the west coast had rain. In the midwestern states, where we expected the moon to be visible, clouds or haze made observations difficult or impossible.

Figure 4 shows locations from which the lunar crescent was sighted. The easternmost location is Washington, DC, where naked-eye sightings were made after the crescent was first located with binoculars. Along the east coast, initial sighting with binoculars was generally necessary for naked-eye observations. There were two exceptions to this. The first was an astronomy class from Appalachian State University in the mountains of North Carolina, in which a group of fifteen students observed the crescent without optical aids. (One student did use binoculars, but care was taken to ensure that he did not influence the other students.) Oddly enough, their instructor did not see the moon. By coincidence the instructor's vision had been checked that day as 20/25. Although the instructor is by no means elderly, this may be an indication that youthful eyes are preferable to experienced eyes. The second exception is enigmatic, and we must consider it as a possible observation. In Blackstone, Virginia, the crescent was apparently sighted by an eight-year-old girl. Her sighting was made at the time we would expect, midway between sunset and moonset. Subsequently she was able to draw the scene; her drawing is consistent with our expectations

(Figure 5). It is impossible to estimate the extent to which her claim of a sighting and her subsequent drawing had been influenced by prior knowledge and imagination. Her instructor, a young adult with good eyesight but a poor horizon, did not see the moon.

In the midwestern states, sightings were made only with binoculars. However, in the Gulf Coast states of Louisiana and Texas, purely naked-eye sightings were reported. From western states the crescent was clearly a naked-eye object.

Conclusions

Of the models tested, the ILDL of Schaefer with extinction coefficient $k_v = 0.3$ best defines the limit of the sightings. Since we had no observers on the Atlantic Ocean, we did not thoroughly test the model of Ilyas. It appears, however, that for this lunar crescent, Ilyas's ILDL provided an optimistic eastern limit of observability. Further observations are needed to test these models. Such observations may lead to a reduction in the width of the zone in which sightings critically depend on observing conditions.

Since the weather cannot be controlled, every effort should be made to aid the observer. Observers should be located with flat, unobstructed western horizons, should know where to look, and should clearly understand what to look for. The use of binoculars is highly recommended. Some observers estimated that their sighting was delayed because the moon appeared somewhat north of where they were looking. One observer initially mistook a small vapor trail for the crescent. Observers who used binoculars invariably sighted the crescent before naked-eye observers. And having once found the crescent with binoculars, the observer had an advantage in making a naked-eye sighting. If these points seems obvious, they are often ignored by people making or judging observations.

This study raises a few questions for future research. Do youthful observers have an advantage in making naked-eye sightings? The possibility of deterioration of the eye with age might be tested by controlled experiments in a planetarium. What role does mass psychology play in group observing? Does the initial report of a sighting stimulate real or imagined sightings by other observers in the group? If secondary sightings are real, do they result from increased concentration or from knowing more precisely where to look?

Acknowledgments

In preparing this observational experiment, we imposed upon the good will of many friends and colleagues. Invariably they responded with interest and good will. Many went well out of their way to make and communicate their observations. When we feel that all reports have come in, we shall publish a list of all participants. Two individuals must be singled out, however. At meetings of the International Astronomical Union in 1985 we were fortunate to meet Dr. Mohammad Ilyas. He discussed his work with us and elicited our interest in a conference on the lunar calendar. In addition, we must acknowledge the interest and assistance of Dr. Bradley Schaefer. He shared his theoretical work with us in advance of publication, and he organized a large group of the observers.

Table 1. Observing Sites

City	ST	Long.	Lat.	Time Zone	Sun-set	Moon-set	Moon's Alt @ SS	Moon's Az @ SS
Hanover	NH	72.3	43.7	EDT	19:48	20:52	9.5	288.7
Weston	MA	71.3	42.4	EDT	19:41	20:44	9.6	288.4
Cambridge	MA	71.1	42.4	EDT	19:40	20:43	9.6	288.4
Montpelier	VT	72.6	44.3	EDT	19:50	20:56	9.6	288.7
Glastonbury	CT	72.6	41.7	EDT	19:45	20:48	9.6	288.3
Stormville	NY	73.7	41.6	EDT	19:49	20:52	9.7	288.3
Hamilton	NY	75.6	42.8	EDT	19:59	21:03	9.7	288.4
Ithaca	NY	76.5	42.4	EDT	20:02	21:06	9.7	288.4
Ocean City	MD	75.1	38.4	EDT	19:49	20:48	9.7	288.0
Washington	DC	77.0	38.9	EDT	19:57	20:58	9.8	288.0
State College	PA	77.9	40.8	EDT	20:04	21:07	9.8	288.1
Easton	PA	75.2	40.7	EDT	19:53	20:56	9.8	288.1
Blackstone	VA	78.0	37.1	EDT	19:58	20:57	9.9	287.8
Chapel Hill	NC	79.1	35.9	EDT	20:00	20:59	9.9	287.8
Greenville	NC	77.4	35.6	EDT	19:53	20:51	9.8	287.8
Boone	NC	81.7	36.3	EDT	20:12	21:11	9.9	287.8
Tampa	FL	82.5	28.0	EDT	20:02	20:55	9.9	287.8
Fort Myers	FL	81.9	26.6	EDT	19:58	20:50	9.8	287.8
Atlanta	GA	84.4	33.8	EDT	20:18	21:16	10.0	287.7
Macon	GA	83.7	32.8	EDT	20:14	21:11	10.0	287.7
Columbus	OH	83.0	40.0	EDT	20:23	21:26	10.0	288.0
Warren	MI	83.0	42.5	EDT	20:28	21:34	10.0	288.3
Lansing	MI	84.6	42.7	EDT	20:35	21:41	10.0	288.4
Tuscaloosa	AL	87.5	33.2	CDT	19:30	20:28	10.1	287.7
Chicago	IL	87.7	41.9	CDT	19:46	20:51	10.0	288.2
New Orleans	LA	90.1	30.0	CDT	19:36	20:31	10.1	287.8
St. Louis	MO	90.2	38.6	CDT	19:50	20:53	10.2	287.9
Columbia	MO	92.2	39.0	CDT	19:58	21:02	10.3	287.8
Des Moines	IA	93.6	41.6	CDT	20:09	21:15	10.3	288.1
Austin	TX	97.7	30.3	CDT	20:06	21:04	10.5	287.6
Mt Locke	TX	104.0	30.7	CDT	20:32	21:31	10.6	287.6
Denver	CO	105.0	39.7	MDT	19:51	20:57	10.6	287.8
Rocky Ford	CO	103.7	38.0	MDT	19:43	20:47	10.6	287.7
Socorro	NM	106.9	34.1	MDT	19:49	20:50	10.7	287.6
VLA	NM	107.6	34.0	MDT	19:52	20:53	10.7	287.6
Tucson	AZ	110.9	32.2	MST	19:02	20:03	10.9	287.6
Flagstaff	AZ	111.6	35.2	MST	19:10	20:13	10.8	287.6
Salt Lake City	UT	111.9	40.8	MDT	20:20	21:29	10.9	287.8
Walla Walla	WA	118.3	46.1	PDT	19:57	21:14	10.9	288.4
Costa Mesa	CA	117.9	33.7	PDT	19:32	20:36	11.1	287.5
Santa Barbara	CA	119.7	34.4	PDT	19:41	20:45	11.1	287.5
Oakland	CA	122.2	37.8	PDT	19:56	21:04	11.3	287.5
Los Angeles	CA	118.4	34.1	PDT	19:35	20:38	11.1	287.5
Pasadena	CA	118.1	34.2	PDT	19:34	20:38	11.1	287.5
Mt Hamilton	CA	121.6	37.3	PDT	19:53	21:00	11.2	287.5
Victoria	BC	123.4	48.5	PDT	20:23	21:45	10.9	288.8

Table 2. Results of Observations

City	ST	No. of Observers	Crescent Sighted	Binoculars Used	Weather
Hanover	NH	1	No		snow
Weston	MA	1	No		snow
Cambridge	MA	4	No		snow
Montpelier	VT	1	No		snow
Glastonbury	CT	1	No		clouds
Stormville	NY	1	No		clouds
Hamilton	NY	1	No		clouds
Ithaca	NY	1	No		clouds
Ocean City	MD	1	No		clouds
Washington	DC	10	Yes & No	Yes & No	haze & cloud
State College	PA	1	No		clouds
Easton	PA	1	No		clouds
Blackstone	VA	2	Yes & No	No	
Chapel Hill	NC	1	No		clouds
Greenville	NC	1	No		clouds
Boone	NC	17	Yes & No	Yes & No	clear, haze
Tampa	FL	3	No		clear, haze
Fort Myers	FL	1	Yes	Yes	
Atlanta	GA	2	No	No	clear
Macon	GA	1	No	No	haze
Columbus	OH	1	No	No	cloudy
Warren	MI	1	No		clouds
Lansing	MI	1	Yes	Yes & No	haze
Tuscaloosa	AL	1	No		haze
Chicago	IL	5	No		clear
New Orleans	LA	1	Yes	No	
St. Louis	MO	1	No		clouds
Columbia	MO	7	No		clouds
Des Moines	IA	1	No	Yes	vapor trails
Austin	TX	2	Yes		
Mt Locke	TX	82	Yes	Yes & No	
Denver	CO	1	No		clouds
Rocky Ford	CO	1	No		clouds
Socorro	NM	1	No		haze
VLA	NM	2	No		clouds
Tucson	AZ	1	No		clouds
Flagstaff	AZ	1	No		clouds
Salt Lake City	UT	1	Yes	Yes	cloud bands
Walla Walla	WA	10	No		thunderstorm
Costa Mesa	CA	1	No		clouds
Santa Barbara	CA	2	No		clouds
Oakland	CA	1	No		fog
Los Angeles	CA	1	No		cloudy
Pasadena	CA	2	No		fog
Mt Hamilton	CA	1	Yes		clouds
Victoria	BC	1	No		clouds

Figure 1.

Predictions of first visibility of crescent moon of April 28, 1987. The curves specify the International Lunar Date Line (ILDL) as predicted by Ilyas and Schaefer. The point of first visibility according to an old Babylonian rule, as used by Yallop is marked in Alabama.

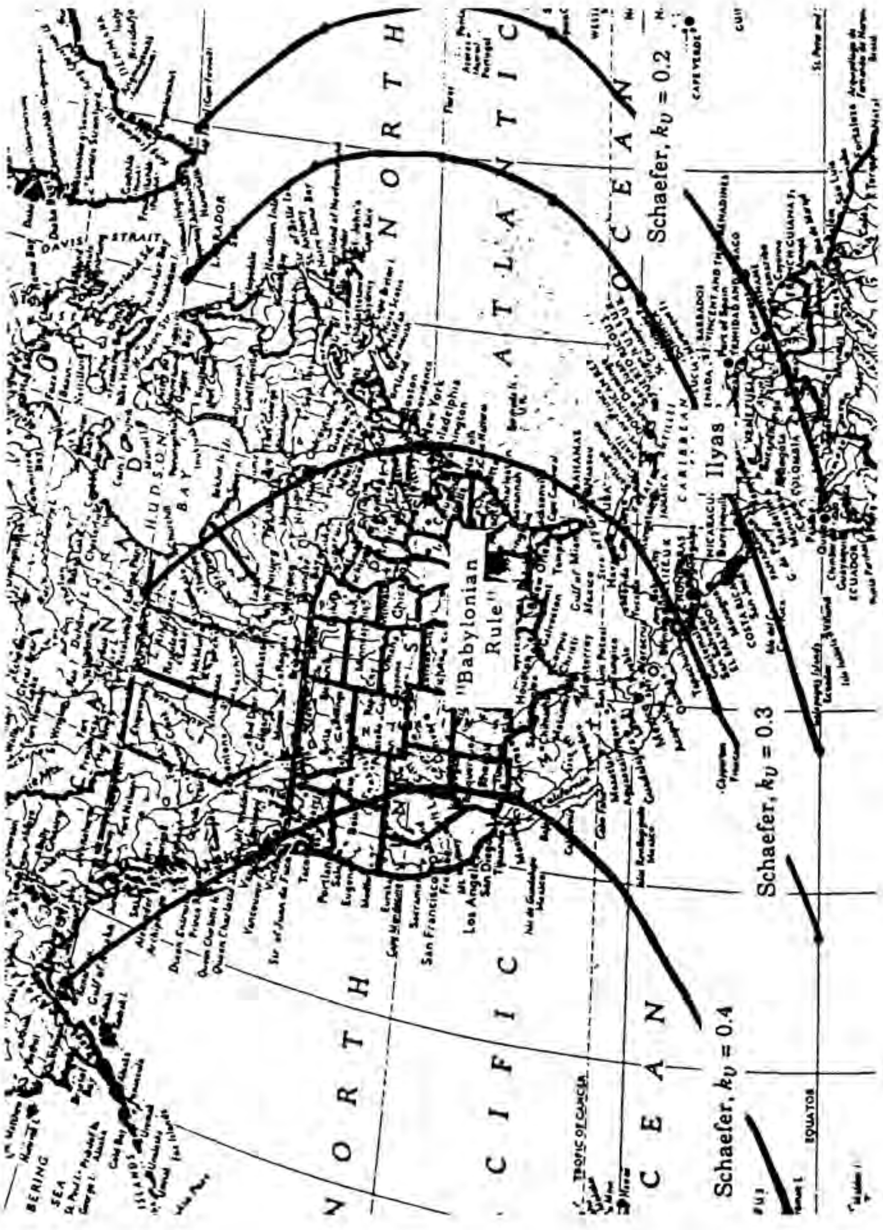


Figure 2.
Locations of Observing Sites, April 28, 1987.

Figure 3.
Weather Satellite Photograph, April 28, 1987, 5:31 p.m., EDT.

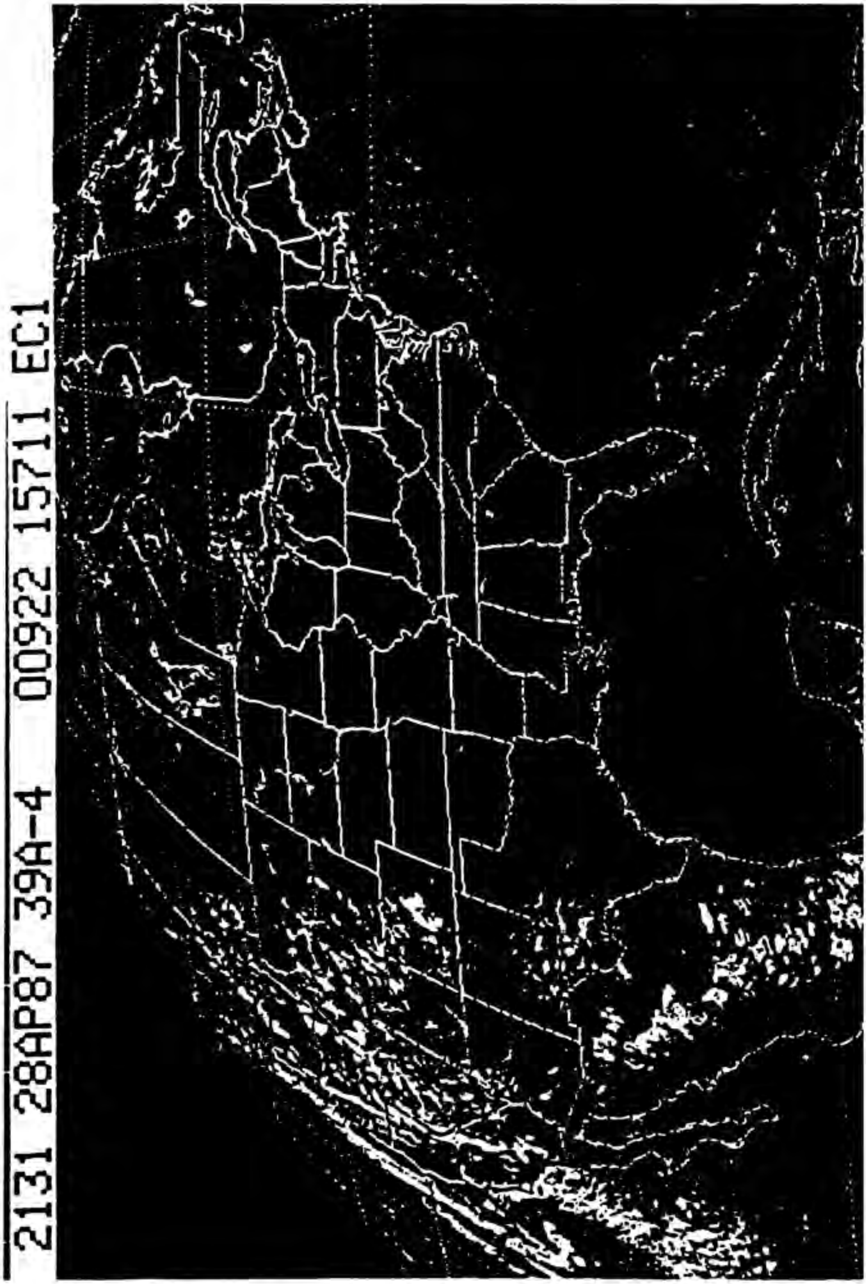
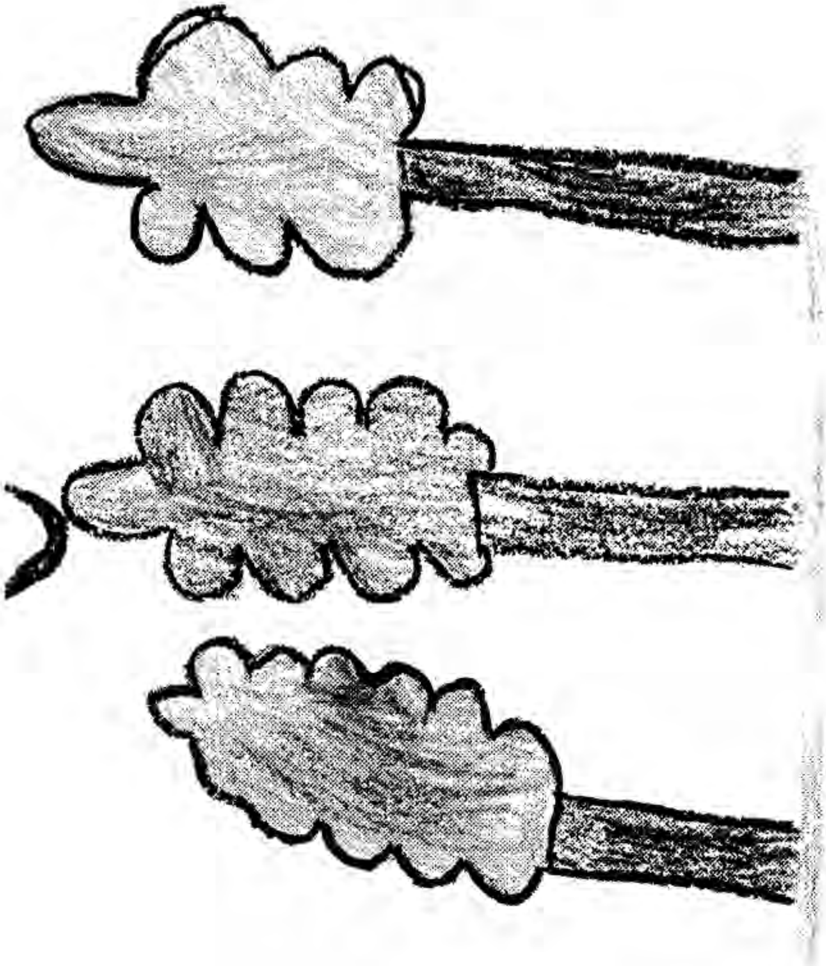


Figure 4.
Sites Where Crescent Moon Was Sighted on April 28, 1987

Figure 5.
Drawing of Lunar Crescent by Takeisha Tucker, Age 8, of Blackstone, Virginia, on April 28, 1987



AN ALGORITHM FOR PREDICTING THE VISIBILITY OF THE LUNAR CRESCENT

Bradley E. Schaefer

Abstract

Dr. Ilyas has called for a better theoretical model of the visibility of the lunar crescent so as to allow for the accurate calculation of lunar date lines. The theoretical approach has a number of fundamental advantages over a purely empirical approach. Theory can account for local conditions, while an empirical rule must assume that weather conditions worldwide are identical to those of the locale where the original data is obtained. Empirical rules take no notice of the important effects of lunar distance or libration. Empirical rules cannot be safely extrapolated past the conditions of the original data. No data exists concerning lunar visibility for telescopic observations, airborne observers, or spaceborne observers, so an empirical method is impossible. The best previous theoretical work has been characterized by Dr. Ilyas as "incomplete and erroneous." Indeed, several of the physical assumptions made are incorrect by over a factor of a thousand. I have approached the problem from a modern astrophysical point of view which includes: (1) extensive photometry of the twilight sky, (2) modeling of atmospheric effects, (3) solving the complex shadowing and forward scattering equations for the lunar surface, (4) incorporating refraction, parallax, pupil diameter, and Stiles-Crawford corrections, (5) the sensitivity of the human eye to detecting an extended source in the shape of a crescent that is unevenly illuminated, and (6) a compact lunar and solar ephemeris accurate to better than an arc-minute for times within several centuries of today. From this model, a computer program has been written which predicts lunar visibility. The FORTRAN program has roughly 60 operative lines with no operation more complex than an arctangent, and it has a fast run time. Versions of the program have been written for drawing lunar date lines and for tele-

scopic observation. This model has been compared with 218 observations which I have compiled. There is excellent agreement between my model and the observations (with the exception of observations 73 and 74 of Fotheringham which the observer himself suggests are in error). The size of the uncertainty zone is roughly 24 degrees in longitude. The lunar date lines calculated by this program are in reasonable agreement with the predictions of Dr. Ilyas, provided that the latitudes are within 40 degrees of the equator and a particular set of observing conditions are assumed. It is found that the longitude of the lunar date lines can be moved by typically 90 degrees depending on whether an "average" or an "excellent" site is being considered. It is hoped that the greatly increased accuracy and the recognition of local conditions will help to spur the acceptance of the lunar date line concept.

Introduction

The visibility of the young crescent moon is an important problem for Islamic calendrics. As such, much effort in the last millennium has gone into constructing prediction algorithms. These efforts can generally be divided into two approaches: empirical and theoretical.

The empirical approach entails the collection of a set of actual observations, from which an empirical rule is derived. In modern times, the only data set used is that compiled by Fotheringham.[1] This data set consists of 76 observations made in Athens, Greece, in the last half of the nineteenth century. From these data, a number of criteria have been established, based (for example) on the time of moonset after sunset or the moon's altitude at sunset.

The best previous theoretical work is that of Bruin.[2] Unfortunately, many of his assumptions are grossly incorrect. For example, his assumed lunar surface brightness is many orders of magnitude in error. Also, he assumes that the twilight sky brightness does not depend on position on the sky for the relevant region, whereas the sky brightness varies by a factor of four. It is naive to equate the visibility of an unevenly illuminated crescent with the visibility of a circular disk of 0.3' diameter as he does. Bruin uses the phys-

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1. J. K. Fotheringham, *Monthly Notices of the Royal Astronomical Society* 70 (1910): 527.

2. F. Bruin, *Vistas in Astronomy* 21 (1977): 331.

iological data of Siedentopf[3] without corrections for color, exit pupil diameter, or binocular vision. Finally, Bruin takes no account for changing observational conditions.

The empirical approach has the advantage that the rule is firmly grounded in actual data. A disadvantage is that the rule is only applicable for observing conditions similar to those of the original data set. This is like saying that the conditions for visibility in the American Southwest are the same as for New England. The effect of observing conditions can easily shift the lunar date line by over 90 degrees of longitude. The theoretical approach has the disadvantage that the algorithm must be checked with real data before acceptance. However, the versatility of the approach allows the visibility to be predicted for a wide variety of conditions (for which no systematic observations may exist). Such cases include those with telescopic assistance, or where the observer is at high latitudes or in an airplane.

With this background, I have set about constructing an algorithm for predicting lunar visibility by modeling the actual physics and physiology of the situation (see the section "Program"). Then I have collected 218 observations for use in evaluating the algorithm (see the section "Observations").

Program

I have separated the act of viewing the moon into more than a dozen processes. Each process is then quantitatively modeled as exactly as possible. In some cases, the information used to construct the model was obtained from professional journals. In other cases, the formulae were obtained from private communication of unpublished work by professionals. Some of the equations are based on data I have collected at astronomical observatories. Many derivations are required to cast the available equations into useful formats. In all, roughly half the algorithm is from unpublished sources.

To calculate the visibility of the early moon my program employs a number of equations which describe various relevant physical phenomena. These equations include the following:

1. The twilight sky brightness for "standard" conditions as a function of the sun's depression angle, the altitude above the horizon, and the azimuth relative to the sun. The relations are calibrated from extensive photometry at the

3. H. Siedentopf, *Astronamiste Nachtrichten* 271 (1940): 193.

Kitt Peak and Cerro Tololo observatories, and with several published studies.

2. The twilight sky brightness under "nonstandard" conditions are related to the brightness under "standard" conditions by a model of atmospheric scattering.
3. The pupil diameter of the eye as a function of sky brightness.
4. A function which varies at a known rate with the age of the observer.
5. The calculation of the geocentric position of the sun and moon to an accuracy of better than an arc-minute for any time within several centuries of the present epoch.
6. The calculation of the topocentric position of the crescent with corrections for the lunar radius and parallax.
7. Finding the apparent position of the crescent after a correction for refraction. The degree of refraction is a function of air temperature, air pressure, and the observer's altitude.
8. Calculation of the sidereal time to an accuracy of better than a second—provided that an accurate longitude is known.
9. Calculation of the altitudes and azimuths of the sun and moon from the information in equations 5 through 8 via standard trigonometric equations.
10. Calculation of the number of airmasses through which a ray of lunar light must pass by an equation which is accurate to the horizon.
11. Determination of the visual extinction coefficient which is the primary source of uncertainty for this program. The extinction can be reasonably estimated for a site given its altitude, humidity, latitude, and date. The basis for this estimation is published and unpublished monthly data for over sixty sites worldwide.
12. The surface brightness of the moon is a complex and rapidly varying function of the angle between the sun and the moon. The calculation involves macro-shadowing, micro-shadowing, and forward-scattering for a distribution of particle sizes.
13. The visibility of an extended light source against some background is a complex problem. The calculations are based on extensive physiological data and the probabilistic model of photon detection. The physiological data are for competent observers of average visual acuity who know the direction and shape of the experimental stimulus.

The program has no "adjustable parameters," since all the equations are based on "first principles." That is to say, I have no empirical correction factors by which to "fudge" the data. Hence, for a given set of observing conditions, only one answer is possible.

The following parameters are needed to run the program:

1. The date of the new moon. This can be expressed as either a Muslim month and year, as a Christian date, or as a Julian date. The latter two input modes need only be accurate to within a week.
2. The observer's latitude and longitude.
3. The altitude of the site.
4. The temperature, pressure, and humidity at the site.
5. The faintest star visible from the site after darkness has fallen.
6. The age of the observer.

These data can be used to estimate the extinction coefficient, or alternatively, the coefficient can be estimated from independent photometric data from a nearby site. Parameters 3 to 6 need only be known approximately, as their effect on the lunar visibility is relatively small (other than through their effect on the estimate of the extinction coefficient). The predominant uncertainty in the result is caused by the uncertainties in the atmospheric clarity. For most conditions, the effects of the uncertainties in the extinction will dominate over the effects of variable visual acuity.

The output of the program is the age of the moon at the time of first visibility for the specified conditions. This can also be expressed as a Julian date or Christian date. My program also computes the arc of vision, arc of light, and the azimuthal separation for comparison with empirical rules. A modification of my program will calculate the position of the lunar date line. A separate modification will calculate the first visibility of the moon when a telescopic aid is used.

The program is written in both Basic and FORTRAN and has roughly sixty operative lines. The most complicated function used is the arctangent. The run time is extremely fast because all the complexity of the program is in the many needed coefficients, instead of in many loops which would slow the execution.

One of the more important results of my program concerns the effect of atmospheric clarity on the position of the lunar date line. For example, the lunar date line will shift by typically 90 degrees when comparing "average" as opposed to "excellent" sites. With the possibility of observing under "poor" conditions, the total uncertainty in the longitude of the lunar date line can easily be 180 degrees. In other words, a prediction algorithm that does not account for observing conditions may only get the correct hemisphere. Of course, most algorithms will do better than this because they are based on nonextreme conditions. But even for nonextreme conditions (say for extinction coefficients between 0.2 and 0.4), the lunar date line will still move by roughly 90 degrees. One conclusion from this is that any algorithm that ignores atmospheric clarity will have a zone of uncertainty at least 90 degrees wide in longitude. Another conclusion is that, after the relative positions of the sun and the moon are considered, the visual extinction coefficient is the most important parameter for predicting visibility.

In his book, Dr. Ilyas[4] has published a set of lunar date lines which can be compared to my program results. In general, I find close agreement between the two algorithms for latitudes within 40 degrees of the equator and for a particular set of observing conditions. This set of observing conditions is just what is to be expected for Athens in the late 1800's. For sites which differ greatly from Athens (e.g., Saudi Arabia, Egypt, Malaysia, the American Southwest, the American East Coast) the predictions of Ilyas will have large systematic shifts in longitude. Fortunately, Ilyas's predictions can be used with confidence from any site if it is more than ninety degrees away from the published lunar date line.

An interesting question is what is the youngest possible visible crescent for a ground-based naked-eye observer? The optimal conditions are the following:

1. the moon is at perigee;
2. the moon is 90 degrees past a node;
3. the observer's latitude is such that the moon stands directly over the sun at the time of best visibility;
4. the observer's longitude is such that the moon's altitude is optimal at the time of best visibility; and
5. the observer has the clearest skies ever known positively to have existed (i.e., an extinction coefficient of 0.10, such as is seen only rarely from Mauna Kea's summit).

Note that just the first two conditions are satisfactorily fulfilled only rarely at new moon (roughly once a decade on average). Even given this rare opportunity, only one restricted area on the earth's surface meets the third and fourth conditions. Of course, the probabilities are low that this restricted area contains one of several sites good enough to satisfy the fifth condition. Then the site must have the rare perfect skies. Finally, a young sharp-eyed observer must be ready and waiting. If all these unlikely conditions are accepted, then my program calculates that a 10-hour old moon (with an angular distance from the sun of 8 degrees) would be marginally visible. It

4. M. Ilyas, *Islamic Calendar, Time and Qibla* (Kuala Lumpur: Berita, 1984).

must be stressed that conditions 1-5 occur, perhaps, once a millenium on average. Relaxing conditions a bit (such as might occur once or twice a century), the minimum observable age will be more like 13 hours.

Observations

Any theoretical model must be tested against real data before acceptance. To this end, I have collected 218 actual observations of the visibility or invisibility of the crescent moon. The majority of the reports were made by professional and amateur observers and are available in the published astronomical literature. Of the unpublished reports, the majority are from the "moon watch" organized by Dr. Doggett on April 28, 1987. Seven remaining observations have been personally collected by me. Thirteen of the 218 reports are for telescopic observation, while 29 are for naked-eye results where a pair of binoculars was used to initially sight the moon. Of the 205 naked-eye reports, 48 are negative sightings where the moon was not detected. Nine reports are observations of the old moon in the morning sky. Roughly half the observations are "critical" in the sense that the moon is only just barely visible or invisible. Eight reports are "trivial" in the sense that the moon was visible on the previous night. (This is not accidental, since recent astronomical literature tends to only report the critical cases.) All reports include the date of observation, the latitude, the longitude, and the details of any optical aid.

For a comparison of the model with the observations, some additional input parameters are needed. The site's altitude can be found from an atlas. The mean temperature, pressure, and humidity for the correct time of year can be found in weather tables. The zenith limiting magnitude in almost all cases will be close to 6.0, although the result is not sensitive to the value chosen here. For most cases, the observer's age is known to within a decade, although once again, this input parameter has only a relatively small effect on the model output.

The above parameters are sufficient to allow an estimation of the visual extinction coefficient. However, in many cases, it is possible to make a better estimate based on photometric data from nearby observatories. To aid in the estimation of atmospheric clarity, I have collected year-round observations from over sixty sites around the world. Unfortunately, I have no photometric data from Athens, Greece, where the many observations of Schmidt and Mommsen were obtained. Currently, I can estimate the extinction to roughly 15 percent in winter and 25 percent in summer.

For each actual lunar visibility observation, the appropriate input parameters were used in conjunction with the model to calculate whether the moon would be visible. In each case, a visibility parameter, R, was calculated, where R is the logarithm of the ratio of the moon's surface brightness to the surface brightness required for marginal visibility at the optimum time of the evening. Hence, a positive value of R implies that the moon should be visible, while a negative value implies invisibility.

A total of 27 (out of 218) model predictions are discrepant in the sense that visibility was predicted yet no moon was seen, or vice versa. The existence of these discrepant predictions is of no surprise, since they are a feature of any model, be it empirical or theoretical. The discrepancies are all for cases of near critical visibility with a lack of perfect knowledge of the observing conditions. This uncertainty in marginal cases translates into an uncertainty in the location of the lunar date line. In effect, there is a zone of uncertainty centered around the lunar date line. In the west end of the zone of uncertainty, the probability of spotting the moon is quite high, while in the east, the probability is quite small.

The R values for the discrepant cases are distributed closely around zero, with the average being 0.03. This implies that the model predictions are well centered in the zone of uncertainty. In other words, the model has no systematic errors. This is encouraging because I have no empirical correction factors to account for any systematic errors.

The 27 discrepant cases can also be used to delineate the width of the zone of uncertainty. For each case, the longitude of the lunar date line at the latitude of the observer was calculated for the relevant parameters. Then the distribution of the longitude differences define the width of the uncertainty zone. For the discrepant cases, the longitude differences are roughly distributed as a Gaussian with a one sigma value of 14 degrees. A comparison with the nondiscrepant cases shows that the probability of a discrepancy falls to 10% when the longitude difference is 12 degrees. Hence, the total width of the uncertainty zone is roughly 24 degrees.

Dr. Doggett of the United States Naval Observatory organized a "moon watch" for April 28, 1987 (the day on which Ramadan started). This "moon watch" was designed to allow for an empirical determination of the lunar date line. These results can then be used to choose among the competing prediction algorithms. The first algorithm, a moonset lag criterion from HM Nautical Almanac Office, gave the easternmost longitude of visibility as 86 west. The second algorithm, that presented by Dr. Ilyas in his book, gave the easternmost longitude of visibility as 40 west. The third algorithm, that presented in this paper, predicted the easternmost longitude of visibility as 75 west for the observing conditions which typically prevail along the eastern coast. Dr. Doggett recruited over fifty observers (primarily astronomers, navigators, and planetarium staff) throughout the United States. Many were clouded out, especially in the Northeast, which had an unseasonably late snowstorm. About 25 of the observers had clear skies. The crescent moon was spotted with the naked eye by many observers including those located in Maryland, Michigan, North Carolina, Florida, Texas, and Louisiana. These sightings indicate that the lunar date line is east of 86 west. However, negative visual sightings were made in Georgia, North Carolina, Michigan, Alabama, Maryland, Iowa, and Florida. This indicates that the lunar date line is significantly west of 40 west. The zone of uncertainty, as defined by these observations, is roughly 20 degrees wide in longitude and is centered on a longitude of 79 west. In summary, of the three prediction programs, the "moon watch" results are in excellent agreement with my program.

Predictions

I have calculated the visibility of the moon for five American cities for the new moons occurring between August 1987 and December 1988 (see the accompanying table). Each entry indicates the age of the moon (in hours) at which it should be first sighted. These predictions are intended both for practical use and as a means to test my model against observations.

Conclusions

It is obvious to any observer of lunar crescents that the observing conditions are an important factor in determining whether the moon is spotted. No previous empirical or theoretical work takes account of observing conditions. In this paper, I have discussed a model of lunar visibility (based on the relevant physics and physiology) which does account for the observing conditions. This model has been implemented as a computer program that is both short and fast.

The real test of the program is in how accurately its model predictions agree with the 218 actual observations I have collected. I find that the agreement between observation and theory is excellent, and that the "zone of uncertainty" is 24 degrees of longitude in width. In particular, the program results are more reliable than any other published algorithm.

It is hoped that the greatly increased accuracy and the recognition of local conditions will help to spur the acceptance of the lunar date line concept.

Age of the Moon at Time of First Visibility

New Moon		Boston	Wash. D.C.	Detroit	Tuscon	Seattle
1987	Aug	60[a]	60[ae]	60[a]	38	63[c]
	Sep	68[a]	46[bf]	68[a]	46	71[c]
	Oct	52	53	53	31[de]	56
	Nov	39	39	39	42	42[d]
	Dec	51[c]	28[def]	28[de]	30	30[de]
1988	Jan	40	41	41	20[e]	43
	Feb	30	31	31	33	34
	Mar	21	21	22	24	24
	Apr	35	36	36	38	39[c]
	May	26	26	27	28	30
	Jun	39	39	40	18[de]	43[c]
	Jul	50[ae]	51[ae]	51[ae]	29	31[d]
	Aug	59[a]	60[ae]	60[a]	38	63[a]
	Sep	66	66[a]	67	45	70
	Oct	72[a]	73[ce]	73[a]	51	76
	Nov	55	56	56	34[c]	58
	Dec	40	40	40	43	43

[a] There is a *very low* probability (less than one percent) that the moon may be sighted 24 hours earlier if the conditions are *extremely* good.

[b] There is a *very low* probability (less than one percent) that the moon may be sighted 24 hours later if the conditions are *extremely* poor.

[c] The site is inside the zone of uncertainty and the moon may perhaps be sighted 24 hours later.

[d] The site is inside the zone of uncertainty and the moon may perhaps be first sighted 24 later.

[e] This prediction disagrees with the prediction of Ilyas.

[f] This prediction disagrees with the prediction of the U.S. Naval Observatory.

Unanimous Statement of Astronomers Participating in the IIIT Lunar Calendar Conference

If the moon is sighted before the instant of conjunction, then by definition, the sighting is of an old moon belonging to the previous lunar month.

The instant of conjunction can be determined by modern astronomical methods to an accuracy of better than a second of time.

For a given lunar month, we can calculate a curved line west of which the new crescent of the moon must be visible on a particular day (local weather conditions permitting).

We can calculate another curved line east of which the new crescent will definitely not be seen until the next evening, when it definitely will be seen.

At high latitudes outside these lines the moon may not be seen on either day and conventions must be adopted to resolve that problem.

Between these two lines is a small **zone of conditional visibility**[1] for which observation is difficult, but if conditions are favorable it is possible for a sighting to occur in this zone. Conflicting reports inside the zone of conditional visibility are due to the *observational* difficulties of detecting the new crescent inside that zone. Reports of a sighting from this zone on the earlier evening must be carefully investigated before acceptance. We recommend that, as a minimum, the age of the observer and questions in the appended "Crescent Sighting Report" (designed by Charles Evans) be

1. It is this zone which the astronomers refer to as the "zone of uncertainty." It is important for nonscientists to bear in mind that the terms "uncertainty" and "error" have a technical meaning for scientists different from that of common parlance. The uncertainty here refers not to mistakes in calculations but to the fact that the actual observation is affected by variations in parameters that cannot be known in advance. The width of this zone is relatively small compared to the circumference of the earth.

asked of the *shāhid*. Other pertinent questions, for example, to ascertain the visual acuity of the observer, should be asked.

It is possible to calculate a time before which initial visibility is impossible. This time is a function of several variables, including lunar age and moonset lag, and it **must** be calculated for each lunation. It corresponds to the easternmost point of the **zone of conditional visibility.**

A moving Lunar Date Line (as described by Ilyas) will generally result in an Islamic day of the month spanning two solar dates. Any moving international lunar date line must result in 29 day months in one part of the world and 30 day months in another part of the world at the same time.

If strict local visibility is required, there will be seasons of months of longer than thirty days at high latitudes.

If strict local visibility is required, then some "villages" in the zone of conditional visibility may see the moon while others *west* of it may not.

From the time the new crescent is first sighted at a given latitude, it will take 24 hours before it can be seen at every point along that latitude.

No matter what basis is used, conventions for the purpose of an international lunar calendar are unavoidable.

Observation from high-flying aircraft deserve investigation as a method which may reduce the width of the zone of conditional visibility.

Astronomy is a physical science distinct from astrology and does not support astrological prediction of human action.

Calculation is not estimation.

Calculation does not require a month of fractional days for *any* system. For example, in a system based on conjunctions, the new month would begin at sunset after conjunction, except at high latitudes where a convention must be adapted for any system, including observed sighting.

Contradictions between countries using calculation are due to the fact that they are calculating different things.[2] If the *fuqaha* provide a uniform

2. Some calculate the time of conjunction before sunset, some the time of conjunction before midnight, some the formation of the cresent defined by an obsolete value of the Danjon limit, some the "optimal time of visibility" according to the "the Babylonian rule," and others the expected time of sightability by various criteria.

definition of what they want calculated, this sort of contradiction should not occur.

After consideration of comments to a first draft provided by all the participants at the conference, the preceding statement was unanimously adopted by the professional astronomers attending the conference:

Imad A. Ahmad (Imad-ad-Dean, Inc.; University of Maryland)
LeRoy Doggett (U.S. Naval Observatory)
Mohammad Ilyas (University Sains Malaysia)
Fakhraddine Karray (University of Illinois)
Ali Kyrala (Arizona State University)
Hussein Kamal-ad-Din
Ahmad Massasati [now at the University of New Orleans, Ed.]
Bradley Schaefer (NASA/Goddard Space Flight Center)

Committee for Crescent Observation Intl.

1069 Ellis Hollow Rd. Ithaca NY 14850 USA *Tel./Fax 607-277-6706 (H)*

Crescent Sighting Report

Date of observation   City/Town

Name: .... Tel.#

Address ....

Exact location from where observed :

When did you see it first: Before sunset   1-2 minutes after sunset   3-5 min. after sunset   6-10 min.
10-15 min. after sunset   20-25 min. after sunset   25-35 min. after sunset

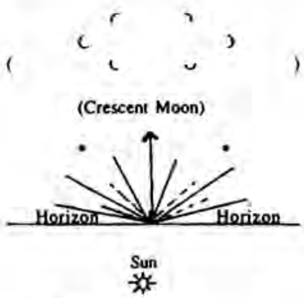
Exact time when you first saw the moon: Using Binoculars .... Naked eye ....

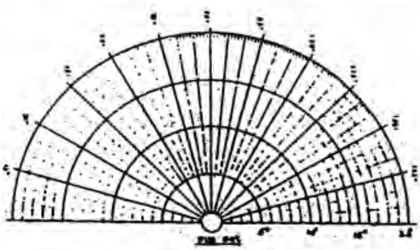
Were you able to see by naked eye? Yes / No   Were others able to see it? Yes / No   Glasses

How long was it visible? Less than a minutes   1-2 minutes   2-10 minutes   10-15-20-25 Min.

Sky conditions where you saw it: Clear blue   Clear white   White Haze   Pink haze
Thin gray clouds   Heavy clouds   Rainy   Foggy
Other ....

Where did you see it? Left or Right of the sunset   High   Very high in the sky   Low   Close to the ground





Mark ↑ at west point

Please make a sketch of the crescent moon as you see it. Be sure to include a reference to TRUE WEST, the position of the sun at sunset, the shape of the crescent and the direction of its horns, any star.

Other witnesses with you: 1. ....

Tel.# ....

Saw by himself   **Yes / No**   **Time**..............   **For how many minutes** ....

2. ....

Tel. #

Saw by himself   **Yes / No**   **Time** ....   **For how many minutes** ....

3. ....

Tel.# ....

AFTERWORD

Not much has improved over the ten years since the initial publication of these conference proceedings. Muslims still disagree over the dates of the *'Id*s and many of the details of the problems discussed in the articles still apply. The mere fact that this volume has been published in a second edition is testimony to the fact that the problem is still with us. Nonetheless, there have been some noteworthy developments—additional refinements in theory, the publication of additional observational data,[1] the availability of websites on the Islamic calendar and downloadable computer programs for calculating moon sighting, the adoption of a sighting convention by a major meeting of Muslim representatives from Pacific Rim countries including the United States, a formal agreement for joint observances by four major American Muslim groups, and some additional insights into the practices of certain Middle Eastern countries followed by many American Muslims who prefer to follow announcements from their home countries rather than restrict themselves to sightings in America. In addition, a proposal I put forward for a *maṭla'* convention has allowed the state of Maryland to publish Islamic holiday dates in advance for the guidance of the school system.[2]

The use of the Internet to help resolve confusion over Islamic dates was addressed at the recently held Muslims and Information Superhighway International Conference.[3] Khalid Shaukat has set up an informative website on the Islamic calendar (www.erols.com/shaukat). Version 4.0 of a reliable computer program for calculating lunar phases produced by Monzur Ahmed may be downloaded from there or from the programmer's website

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1. L. E. Doggett, and B. E. Schaefer, *Icarus* 107 (1994): 388.

2. I. A. Ahmad, *A Uniform Calendar for the Western Hemisphere* (Bethesda: Imad-ad-Dean, 1990).

3. I. A. Ahmad, "Necessary Elements in an Islamic Calendar Website," submitted to *Islamic Horizons* (1998). S. K. Shaukat, "Astronomy Serving Islam Through the Internet," submitted to *Islamic Horizons* (1998).

(www.ummah.org.uk/ildl/mooncalc.html). It contains a choice of criteria for determining the date line including some by Muhammad Ilyas.

In particular, readers' attention is drawn to the criterion called "Ilyas_C" which follows the recommendations of the Pacific Rim countries meeting at Subung Jaya in Malaysia in 1988.[4] The conference was a follow-up to our own conference and built on the foundations established here. A specific criterion was suggested based on the simplicity and reliability of a minimum altitude and azimuth separation between the sun and moon when the sun is below the horizon. In its simplest form this recommendation is to consider the moon sightable where the azimuthal difference is zero and the altitude difference 10.5 plus or minus .5 degrees. Unfortunately, the published version of the recommendations gives no specific threshold nor does it suggest a time after sunset at which these conditions should hold. The threshold suggested at the conference was actually 9.5 degrees (that is, at the two sigma level of rejection) and I myself use that value when the sun is 5 degrees below the horizon. This is slightly liberal, but that liberality has been politically helpful given the near impossibility of convincing Muslim moon sighters that they may be mistaken when the sighting is scientifically possible.

Another important development has been the agreement among the Islamic Society of North America, the Islamic Circle of North America, the Ministry of W. Deen Mohammad, and the Jamaat Community of Imam Jamil al-Amin to observe uniform dates based on certain crescent sighting guidelines. Some have questioned whether this group, the "Islamic Shura Council of North America," has followed its own guidelines. In January 1998, however, the guidelines were followed and the overwhelming majority of American Muslims observed the *'Id al-Fitr* on the same day. Some dissenters observed the *'Id* on the following day, arguing that sightings with binoculars should not have been accepted and/or that there should have been a minimum of fifty (or some other large number of) witnesses. Siddiqui,[5] however, informed me that the Shura Council accepts binocular sightings as consistent with fiqh. In any case, there is no minimum number of witnesses specified in the published criteria.[6] I propose that such disputes

4. M. Ilyas and M. Khalid-Taib, *Internationalization of the Islamic Calendar* (Penang: Universiti Sains Malaysia, 1988).

5. M. Siddiqui, private communication (1998).

6. W. D. Mohammed, J. al-Amin, A. M. Mujahid, and A. I. Ali, *Islamic Horizons* Jan./Feb. (1996): 12.

be avoided by adopting a *maṭla'* that permits sightings from anywhere that shares part of the night with our East Coast.[7] Thus, a party on a boat or in a jet off the coast of California consisting of however many people it would take to satisfy the dissenters could have sighted the *hilal* crescent of Shawwal, with or without binoculars.

Why certain Muslim countries continue to report sightings which are scientifically impossible still remains unanswered. Saudi Arabia and Egypt are especially problematical because of the large numbers of Amercian Muslims who follow their lead. If a sighting in Saudi Arabia were valid, then a sighting later, from North America, should be inevitable since sunset takes place in the Eastern Time Zone about eight hours later (and even later further west). Despite claims that the Egyptians require conjunction at least four or five minutes before sunset, the Egyptians began fasting in December of 1997 by accepting an earlier moon sighting claim. The Saudis are even more problematical. Based on what appears to be a biased sample of reported Saudi dates, Schaefer[8] has made the claim that "the majority of Ramadans have been started based on reported crescent sightings before the time of New Moon." Shaukat[9] reports that the Umm al-Qura calendar strictly follows a pattern of declaring a new month if the lunar conjunction takes place after midnight Greenwich time in the nautical Almanac. If the Saudis are open to accepting moon sightings (whether scientifically possible or not) on the 29th of the month on that calendar then the reason for their pre-conjunction Ramadans and *'Id*s becomes evident.

The most important conclusion republished here has been the most ignored. It is the unanimous statement of the astronomers that the need for adopting conventions is unavoidable. The confusion that continues despite the progress reported above is due to the fact that Shura Council's criteria are unclear and/or disputed as to the number, location, means, and certification of sightings. The American Muslim Council has published a pocket calendar with *'Id* dates calculated using conventions mentioned above[10] and it has become the basis of calendars used by the University of Michigan, the Maryland public school system, and the Yearbook of American and

7. Ahmad, *A Uniform Calendar for the Western Hemisphere*.

8. B. E. Schaefer, *Bulletin of the American Astronomical Society* 29 #5 (1998): 1206.

9. S. K. Shaukat, private communication (1997).

10. Ahmad, *A Uniform Calendar for the Western Hemisphere*.

Canadian Churches. This has allowed the public schools in Maryland, for example, to advise teachers against scheduling exams on Muslims' *'Id* days. It is my dream that the republication of these proceedings will bring about a broader recognition that some set of conventions must be adopted, published, and strictly followed. This would make possible the national consensus on Islamic dates that has eluded us so far.

Imad-ad-Dean Ahmad
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Dhu al-Hijjah 1418 A.H.

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Papers Presented at the Annual Islamic Economics Discipline Group of AMSS

Edited by Zaidi Sattar

The book is a collection of the work of a group of economists committed to the advancement of Islamic economics. This collection, which is representative of the thinking of economists of the Muslim world, attempts to define the principles of managing a country's resources within the framework of Islamic principles.

The authors challenge the view that western capitalism holds a universal answer for all societies and argue that an Islamic system guided by the principles laid down in the Qur'an and embracing economic relationships of property ownership, work compensation, profit and loss, and risk taking provides a viable alternative, one that governs not only economic activity but the complete development of the human person—spiritual, moral, and economic. The authors do not view economics in isolation but as an essential element of social growth determining the mobilization and sharing of the resources of the Muslim state.

The human element cannot be ignored in resource development. To quote from Dr. al Alwani's foreword to this book: *"It is natural that development at every stage, at the stage of knowledge, of worship, of culture to be connected at the level of its foundation with the human element."* This collection will serve as a compendium of ideas and contemporary thinking on economic issues in the Muslim world as seen by leading Muslim scholars.

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- To provide a comprehensive Islamic outlook through elucidating the principles of Islam and relating them to relevant issues of contemporary thought;
- To regain the intellectual, cultural, and civilizational identity of the Ummah through the Islamization of the humanities and social sciences; and
- To rectify the methodology of contemporary Islamic thought in order to enable it to resume its contribution to the progress of civilization and give it meaning and direction in line with Islamic values.

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About This Book

This volume brings together both the elementary scientific facts that any lunar calendar formulation cannot ignore and a summary of the pressing scientific questions of particular interest to the Islamic calendar. Scientific aspects of the problem are thoroughly reviewed without prejudicing the argument in purely Islamic juridical questions and differences. The results are of great significance to both Islamic scholars and the general Muslim public.

The papers presented are of a high scientific quality and are followed by a unanimous statement of the professional astronomers on the scientific questions. If these conclusions are followed, the varying sets of conventions used by different Islamic populations can be made self-consistent and free from scientific errors, even if they still differ from each other. This new edition allows the correction of errors in the first edition, makes the style more uniform among the papers, and improves the articles' graphs and figures. It aims to serve as an effective tool for addressing the calendrical issues that motivated the conference more than being merely an historical record. A new Afterword summarizes refinements in the scientific issues that have taken place in the ten years since the conference, many of which were prompted by the work presented here.