Science in the service of religion: the case of Islam

David A. King

In Islam, as in no other religion in human history, the performance of various aspects of religious ritual has been assisted by scientific procedures. The organization of the lunar calendar, the regulation of the astronomically defined times of prayer, and the determination of the sacred direction of the Kaaba in Mecca—these are topics of traditional Islamic science still of concern to Muslims today, and each has a history going back close to fourteen hundred years. But the techniques advocated by the scientists of medieval Islam on the one hand and by the scholars of religious law on the other were quite different, and our present knowledge of them is based mainly on research conducted during the past twenty years on one small fraction of the vast literary heritage of the Muslim peoples.

Most historians of Islamic science have concentrated on scientific knowledge which was transmitted to the West; by so doing they have tended to overlook the essence of Islamic science. Indeed, most modern accounts of science in the medieval Islamic world, whether by Western or Muslim writers, have ignored what may well be called the Islamic aspects of Islamic science. These have been researched recently, using the vast amount of relevant medieval Arabic manuscripts available in libraries around the world; most of the results of this research have appeared in scholarly journals not easily obtainable outside academic libraries. The time is therefore ripe for an overview. In fact, this article is the first attempt in the non-scholarly literature to survey the way in which science, particularly astronomy, has been used for purposes relating to Muslim religious life for well over a millennium. Even so, it is not an overview of Islamic astronomy in general, for it deals with only three of the many topics dealt with by the scholars of medieval Islam.

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To understand Muslim activity in this domain we must realize that there were two main traditions of astronomy in the Islamic Near East, *folk astronomy* and *mathematical astronomy*. Folk astronomy, based on naked-eye observation of celestial phenomena and devoid of theory or computation, has generally been overlooked by historians of science with their predilection for hard-core scientific achievements. Yet, as we shall see, it was far more influential in Islamic society than mathematical astronomy, which as the name indicates was based on systematic observation, theory and mathematical procedures.

A historical investigation of the Islamic aspects of Islamic science provides answers to several questions. First, why is there so much confusion in the modern Islamic world about the determination of the beginning of Ramadan, the sacred month of fasting? Second, why are there five prayers in Islam? These are not specifically prescribed in either the Koran, the ultimate source of Islamic sacred law, or the hadith, the literature dealing with the sayings and practice of the Prophet Muhammad, the second main authority for the sacred law of Islam. Third, why are medieval mosques invariably not oriented properly towards Mecca? This problem has often puzzled those few historians of Islamic architecture who have taken the trouble to measure mosque orientations, but, as we shall see, it is now largely resolved, thanks to the evidence of newly discovered medieval texts. Furthermore these texts cast new light on the significance of the Kaaba itself and on its original function.

Folk astronomy and mathematical astronomy

The Arabs of the Arabian peninsula before Islam had an intimate acquaintance with the sun, moon and fixed stars, the seasons, the changing night sky and weather patterns throughout the year. Since the sun, moon and stars, as well as the winds and rains, are mentioned in the Koran, a truly Islamic cosmology (quite independent from the tradition adapted from Greek sources by Muslim scientists) developed in the vast corpus of the Koranic commentaries and in separate treatises on the glory of God as revealed by His creation. Since, in addition, the Koran encourages Man to use the stars for guidance, a basic knowledge of the heavens was considered advantageous. Folk astronomy, based on what could actually be seen in the sky throughout the year and innocent of any underlying theory or associated computus, thus became widespread in the Islamic Near East and remained so throughout medieval times. The basics of this subject are outlined in encyclopaedias and a series of special treatises compiled over many centuries, and its application to religious needs is discussed in books dealing with the sacred law of Islam.

The period from the eighth to the fourteenth or fifteenth centuries saw the flourishing in the Near East of a different kind of astronomical knowledge. Muslim astronomers, heirs to the sophisticated astronomical traditions of the Hellenistic world, and also of Iran and India, made new observations, developed new theories, compiled new tables, and invented new instruments. They produced an enormous corpus of scientific literature covering all subjects from cosmology to computational techniques, and they made progress in all branches of their discipline. But the scientists did not have a wide audience. They wrote mainly technical treatises which circulated only within the scientific community, and few of them compiled popular summaries. In particular, the solutions they proposed for problems relating to religious ritual were generally considered to be too complicated or even completely irrelevant.

We now consider three facets of Islamic religious practice involving astronomy. As we shall see, the simple techniques of folk astronomy were applied to these practical problems by the legal scholars, and the complicated techniques of mathematical astronomy were applied to the same problems by the astronomers. The former, generally disinclined to listen to the opinions of scientists, had far greater control over the practice of the people than had astronomers. On the other hand, the solutions developed by Muslim scientists, invariable too complicated for widespread application in the medieval milieu, are impressive indeed from a scientific point of view.

The regulation of the lunar calendar

The Islamic calendar is strictly lunar. The beginnings and ends of the lunar months, in particular of the holy month of Ramadan, and various festivals throughout the twelve-month 'year', are regulated by the first appearance of the lunar crescent.

Since twelve lunar months add up to about 354 days, the twelve-month-cycles of the Islamic calendar occur some eleven days earlier each year, and the individual months move forward through the seasons. To keep the lunar months in line with the seasons of the solar year it was the custom in pre-Islamic times to insert an additional 'intercalary' month in the lunar calendar every few years. This practice the Prophet Muhammad abandoned. The Koran expressly forbids such intercalation, and the exegetes explain that the proscription was necessary because intercalation caused months that God had intended to be holy to be confused with other months.

For scholars of the sacred law, the month began with the first sighting of the crescent moon. This observation is a relatively simple affair, provided that one knows roughly where and when to look and the western sky is clear. Witnesses with exceptional eyesight were sent to locations that offered a clear view of the western horizon, and their sighting of the crescent determined the beginning of the month; otherwise they would repeat the process the next day. If the sky was cloudy, the calendar would be regulated by assuming a fixed number of days for the month just completed. Also, the crescent might be seen in one locality and not in another. Unfortunately the historical sources contain very little information on the actual practice of regulating the calendar.

Astronomers, on the other hand, knew that the determination of the possibility of sighting on a given day was a complicated mathematical problem, involving knowledge of the positions of the sun and moon and the mathematical investigation of the positions of the both celestial bodies relative to each other and to the local horizon (see figure 1). In short, the lunar crescent will be seen after sunset on a given evening at the beginning of a lunar month if it is far enough away from the sun, and if it is high enough above the horizon not to be overpowered by the background sky glow. Conditions required to assure crescent visibility on most occasions can be determined by observation, but the formulation of a definitive set of conditions has defied even modern astronomers. The positions of the sun and moon must be investigated to see whether the assumed visibility conditions are satisfied, but, even if they are, the most ardent astronomer can be denied the excitement of sighting the crescent at the predicted time if clouds or haze on the western horizon restrict his view.

The earliest Muslim astronomers adopted a lunar visibility condition which they found in Indian sources. It was necessary to calculate the positions of the sun and moon

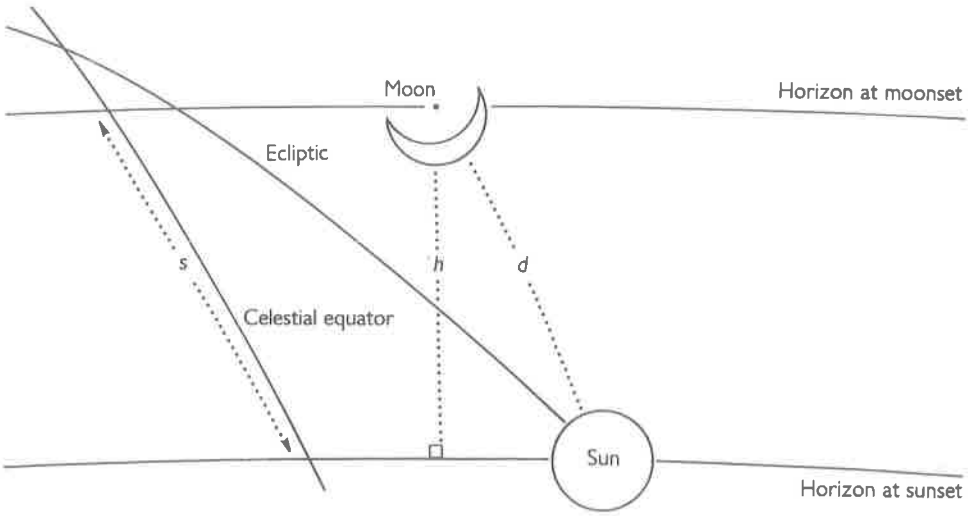


Figure 1. The western horizon at sunset on the evening of first visibility of the crescent moon. For predicting visibility Muslim astronomers devised sets of conditions on such quantities as the apparent distance between the sun and moon (*d*), the altitude of the moon above the horizon at sunset (*h*), and the difference in setting times of the sun and moon (*s*).

from tables and then to calculate the difference in setting times over the local horizon. If the latter was 48 minutes or more, the crescent would be seen, if it was less the crescent would not be seen. Based on this condition and computed specifically for the latitude of Baghdad, the astronomer al-Khwarizmi in the early ninth century compiled a table showing the minimum distances between the sun and moon (measured on the ecliptic) to ensure crescent visibility throughout the year.

During the following centuries Muslim astronomers not only derived far more complicated conditions for visibility determination but also compiled highly sophisticated tables to facilitate their computations. Some of the leading Muslim astronomers proposed conditions involving three different quantities, such as the apparent angular separation of the sun and moon, the difference in their setting times over the local horizon, and the apparent lunar velocity. Annual ephemerides or almanacs gave information about the possibility of sighting at the beginning of each month (see figure 2). In brief, the achievements of the Muslim astronomers in this area were impressive.

In modern times the regulation of the calendar has led to controversy between religious authorities and scientists. The main problems are the difficulty of making sure predictions for a multiplicity of locations and the unwillingness of the religious authorities to listen to the scientists. For example, Ramadan has sometimes been announced one, or even two, days early in some Islamic countries. (see, for example, *Al-Ahram*, Cairo, 26 and 27 September 1973). This occurrence, unthinkable in medieval times, resulted not only from the enthusiasm to begin the fast, but also from the ineptitude of the responsible authorities in matters scientific. Modern communications and divergent political interests also played a role. An international commission has recently been formed to handle problems associated with the Islamic calendar, happily under the enlightened leadership of an astronomer, Dr. Mohammed Ilyas of Malaysia.

Figure 2. A table showing visibility predictions for the first evening in each month of the *civil* calendar during the year 1129 Hijra (=1716/17). Calculations of the positions of the sun and moon relative to each other and relative to the local horizon lead to pronouncements such as the crescent 'will be seen clearly', 'will be seen with difficulty', or—in the case of Ramadan that year—'will not be seen at all'. In the last case the religious authorities would have announced the beginning of Ramadan the following evening. Numbers in these and other medieval tables were written in the standard alphanumerical system (called *abjad* in Arabic) and are expressed sexagesimally, that is to base 60—as in modern notation for angles in degrees and minutes or time in hours and minutes. (Courtesy of the Egyptian National Library.)

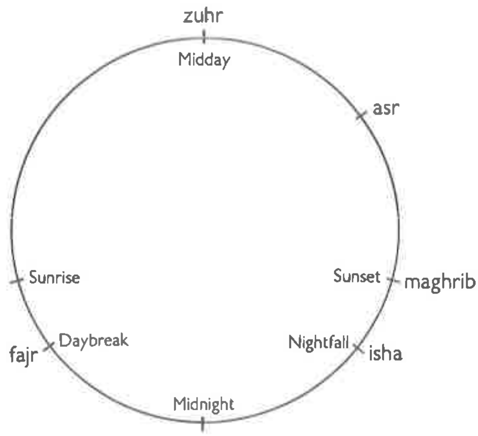
The regulation of the five daily prayers

The times of the five daily prayers in Islam are defined in terms of astronomical phenomena dependent upon the position of the sun in the sky. More specifically, the times of daylight prayers are defined in terms of shadows, and those of night prayers in terms of twilight phenomena. They therefore vary with terrestrial latitude, and unless measured with respect to a local meridian, also with terrestrial longitude.

Because the months begin when the new moon is seen for the first time shortly after sunset the Islamic day is considered to begin at sunset. Each of the five prayers in the Islamic day (see figure 3) may be performed during a specified interval of time, and the earlier during the interval that the prayer is performed, the better.

Figure 3.

The five standard prayers of Islam and their timings. The three prayers at night are regulated by horizon and twilight phenomena and the two daylight prayers by means of shadow lengths.



The day begins with the *maghrib* or sunset prayer. The second prayer is the *isha* or evening prayer, which begins at nightfall. The third is the *fajr* or dawn prayer, which begins at daybreak. The fourth is the *zuhr* or noon prayer, which begins shortly after astronomical midday when the sun has crossed the meridian. The fifth is the *asr* or afternoon prayer, which begins when the shadow of any object has increased beyond its mid-day minimum by an amount equal to the length of the object casting the shadow. In some medieval circles, the *zuhr* prayer began when the shadow increase was one quarter of the length of the object, and the *asr* prayer continued until the shadow increase was twice the length of the object—see figure 4. In other communities, a prayer at midmorning, called the *duha*, began at the same time before midday as the *asr* began after midday. This prayer is mentioned in the hadith, and there are varying accounts about it. In some the Prophet is said to have performed it himself. In others, he is said to have declared it a heretical innovation. This is a clear indication that later authorities were undecided about whether or not to include it in the daily ritual.

The five prayers adopted by the Muslim community are not specifically mentioned in the Koran. In the hadith literature, more than five prayers are mentioned but no specific definitions are given in their times. The *duha* prayer at midmorning was clearly practised by some in the early Muslim community, but later it was generally, although not completely, abandoned. Also there is reference to the night-vigil called *tahajjud*; this was later made optional. The standard definitions of the times for the daytime prayers in terms of shadow *increases* rather than shadow *lengths* (as mentioned in the Prophetic hadith quoted above) first appear in the eighth century.

The reason why five prayers were adopted by the early Muslim community is clear from the definitions of their times. The definitions of the *duha*, *zuhr*, and *asr* prayers in terms of shadow increases provide simple and practical means for regulating them at the ends of the third, sixth and ninth hours of daylight, the hours being seasonal hours, that is, one-twelfth divisions of the length of daylight. Seasonal hours, which vary in duration throughout the year, were in standard use in the Near East in Antiquity. The relationship between these and the shadow increases is provided by a simple, approximate formula for timekeeping of Indian origin known to the Muslims in the eighth century. Even the names of the prayers in Islam are the same as those of the corresponding seasonal hours recorded by some of the Arab lexicographers. Their

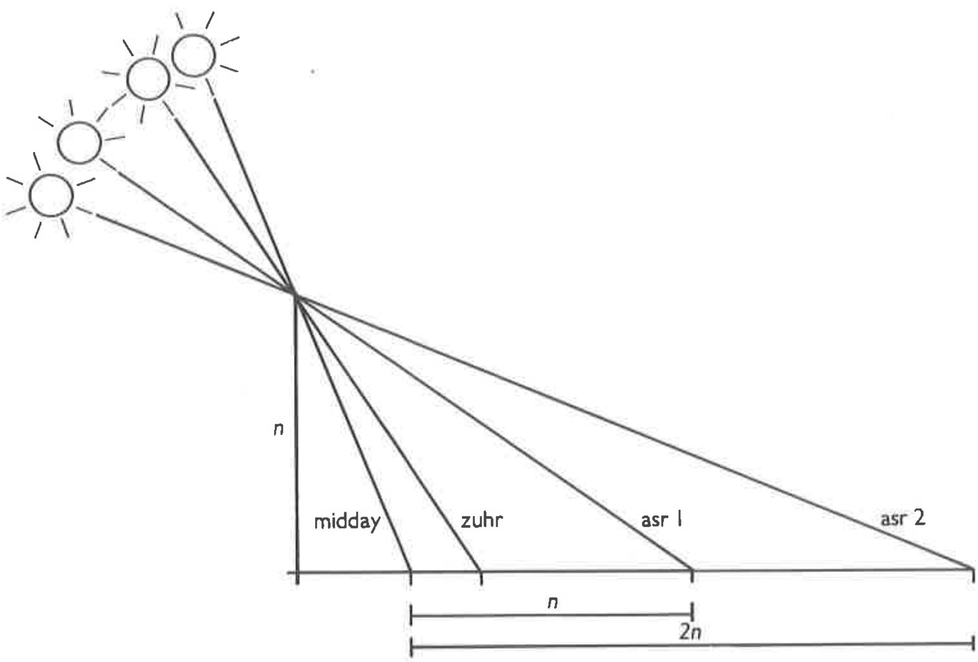


Figure 4. The times of the *zuhr* and the *asr* prayers are defined in terms of the increase of the shadow of a vertical object over its midday minimum. Thanks to medieval texts on folk astronomy these curious definitions have now been explained.

times correspond to the times of the seven prayers of early Syrian Christianity, but with the omission of the prayer at sunrise because it was expressly forbidden by the Prophet and the dropping of the prayer at midmorning in all but a few communities.

In the first few decades of Islam, the times of prayer were regulated by observation of shadow lengths by day and of twilight phenomena in the evening and early morning. Precisely how either the daylight or the night-time prayers were regulated is unfortunately not clear from the available historical sources. Muezzins who performed the call to prayer from the minarets of mosques were chosen for their piety and the excellence of their voices, but their technical knowledge was limited to the basics of folk astronomy.

On the other hand, the determination of the precise moments (expressed in hours and minutes, local time) when the prayers should begin, according to the standard definitions, required complicated mathematical procedures in spherical astronomy, that is the study of problems associated with the apparent daily rotation of the celestial sphere. Accurate as well as approximate formulae for reckoning time of day or night from solar or stellar altitudes were available to Muslim scholars from Indian sources and these were improved and simplified by Muslim astronomers. Certain individual astronomers from the ninth century onwards applied themselves to the calculation of tables for facilitating the determination of the prayer-times. The earliest prayer-tables were prepared by al-Khwarizmi for the latitude of Baghdad. The first tables for finding the time of day from the solar altitude or the time of night from the altitudes of certain prominent fixed stars appeared in Baghdad in the ninth and tenth centuries. The extent

Figure 5. An extract from the main corpus of astronomical tables for regulating the times of the prayers in medieval Cairo. These tables, discovered only in 1970, cast considerable light on contemporary religious practice. This extract displays for each degree of solar longitude, corresponding roughly to each day of the year, the time from sunset until the moment when the muezzin should extinguish the candles on the minarets during the month of Ramadan. (Courtesy of the Egyptian National Library.)

to which these tables deriving from mathematical procedures were used before the thirteenth century is unknown; the earliest examples are contained in technical works which must have had fairly limited circulation. The muezzins certainly had no need of them. One had to be an astronomer, for they had to be used together with some kind of observational instrument for measuring the sun's altitude and reckoning the passage of time.

It was not until the thirteenth century that the institution of the *muwaqqit* appeared in mosques and madrasas. These professional astronomers associated with a religious institution not only regulated the prayer times, but constructed instruments, wrote treatises on spherical astronomy, and gave instruction to students. In thirteenth-century Cairo, new tables were compiled which set the tone for astronomical timekeeping all over the Islamic world in the centuries that followed. In medieval Cairo there was a corpus of some 200 pages of tables available for time-keeping by the sun and for regulating the times of prayer (see figure 5).

Impressive innovations in astronomical timekeeping were made in other medieval cities, especially Damascus, Tunis and Taiz, although by the sixteenth century Istanbul had become the main centre of this activity. We may mention, for example, highly sophisticated tables of special trigonometric functions especially designed to solve problems of spherical astronomy for any latitude. Tables for finding the time of day from the solar altitude at any time of year were compiled for Cairo, as we have mentioned, and also for Damascus, Tunis, Taiz, Jerusalem, Maragha, Mecca, Edirne and Istanbul. Medieval tables for regulating the times of prayer have been found for a series of localities between Fez in Morocco and Yarkand in China. Such tables have a history spanning the millenium from the ninth century to the nineteenth.

As noted above astronomical tables for regulating the prayer-times had to be used together with instruments. Only in this way could one ascertain that the time advocated in the table had actually arrived. The most popular of these instruments were the astrolabe and the quadrant. Hundreds of Islamic astrolabes and several dozen quadrants are preserved in the museums of the world, a small fraction of the instruments actually made by Muslim astronomers. An alternative means of regulating the daytime prayers was available to the Muslims in the form of the sundial. Many mosque sundials from the later period of Islamic astronomy survive to this day, though most are non-functional.

The call of the muezzin is to be heard every day in towns and villages all over the Islamic commonwealth, and the call to prayer is also broadcast on radio and television. But muezzins and technicians now read the prayer-times from tables found in pocket diaries, wall calendars, and daily newspapers. The times are usually computed by local survey departments or other agencies acceptable to the religious authorities, who apply modern methods to definitions which have been standard for over a millenium. Recently clocks and watches have appeared on the market which beep at the prayer-times and reproduce a recorded prayer-call—a far cry indeed from observing shadow lengths or reckoning prayer-times with an astrolabe or sophisticated astronomical tables.

The determination of the sacred direction

The *Kaaba* is a shrine of uncertain historical origin which served as a sanctuary and centre of pilgrimage for the Arabs for centuries before the advent of Islam. It was adopted by the Prophet Muhammad as the focal point of the new religion, and the Koran advocates prayer towards it. For Muslims it is a physical pointer to the presence of God. Thus since the early seventh century Muslims have faced the Sacred Kaaba in Mecca during their prayers. Mosques are built with the prayer-wall facing the Kaaba, the direction being indicated by a *mihrab* or prayer-niche. In addition, certain ritual acts such as reciting the Koran, announcing the call to prayer, and slaughtering animals for food, are to be performed facing the Kaaba. Also Muslim graves and tombs were laid out so that the body would lie on its side and face the Kaaba. (Modern burial practice is slightly different but still Kaaba-oriented.) Thus the direction of the Kaaba—called *qibla* in Arabic and all other languages of the Islamic commonwealth—is of prime importance in the life of every Muslim.

In the first two centuries of Islam, when mosques were being built from Andalusia to Central Asia, the Muslims had no truly scientific means of finding the qibla. Clearly they knew roughly the direction they had taken to reach wherever they were, and the direction of the road on which pilgrims left for Mecca could be, and in some cases actually was, used as a qibla. But they also followed two basic procedures, observing tradition and developing a simple expedient.

In the first case, some authorities observed that the Prophet Muhammad had prayed due south when he was in Medina (north of Mecca) and they advocated the general adoption of this direction for the qibla. This explains why many early mosques from Andalusia to Central Asia face south.

Other authorities held that the Koran required one to stand precisely so that one faced the Kaaba. Now the Muslims of Meccan origin knew that when they were standing in front of the walls or corners of the Kaaba they were facing directions specifically associated with the risings and settings of the sun and certain fixed stars. The major axis of the rectangular base of the edifice is said to point towards the rising point of Canopus, and the minor axis is said to point towards summer sunrise and winter sunset (see figure 6). These assertions about the Kaaba's astronomical alignments, found in newly-discovered medieval sources, have been confirmed by modern measurements. In addition, Arabic folklore associates the sides of the Kaaba with the winds and rain. These features and associations cast new light on the origin of the edifice, and in a sense confirm the Muslim legend that the Kaaba was built in the style of a celestial counterpart called the *bayt al-ma'mur*: indeed it seems to have been an architectural model of a pre-Islamic Arab cosmology in which astronomical and meteorological phenomena are represented. The religious association was achieved first by a number of statues of the gods of the pagan Arabs which were housed inside it. With the advent of Islam these were removed, and the edifice has for close on 1400 years served for Muslims as a physical pointer to the presence of God.

The corners of the Kaaba were associated even in pre-Islamic times with the four main regions of the surrounding world, Syria, Iraq, the Yemen, and 'the West'. Some Muslim authorities said that to face the Kaaba from Iraq, for example, one should stand in the same direction as if one were standing right in front of the north-eastern wall of the Kaaba. Thus the first Muslims in Iraq built their mosques with the prayer-walls towards winter sunset because they wanted the mosques to face the north-eastern

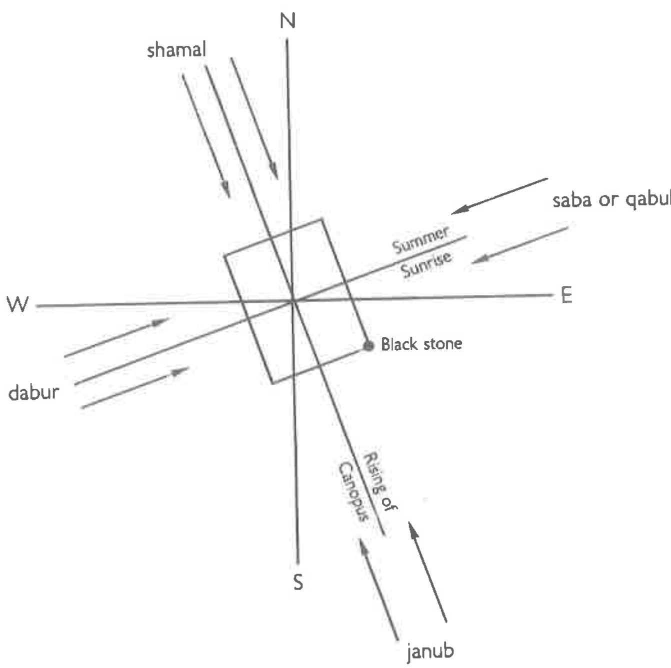


Figure 6.

The orientation of the rectangular base of the Kaaba towards the rising of Canopus and summer solstice, as recorded in various medieval sources. The 'cardinal' winds are shown, each one striking a wall of the Kaaba head-on.

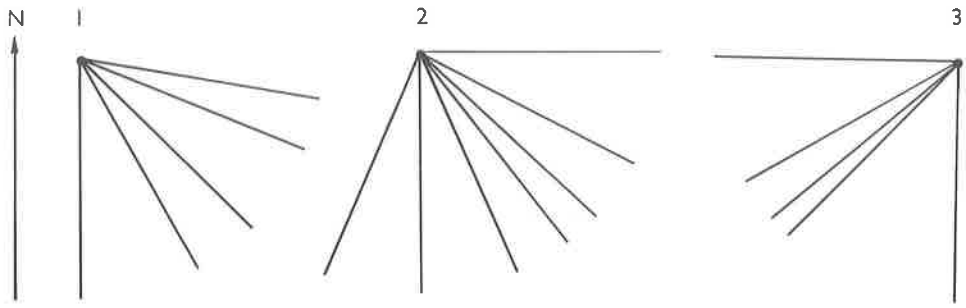


Figure 7. The various qiblas used for mosque orientations in (1) Cordova, (2) Cairo, and (3) Samarqand, as reported in medieval sources. Cardinal directions were used, as well as solar and stellar risings and settings, and—last but not least—mathematically computed directions based on complicated accurate and/or simple approximate formulae. (For details see King, 'The Sacred Direction in Islam...', p. 325.)

wall of the Kaaba. Likewise the first mosques in Egypt were built with their prayer-walls facing winter sunrise so that the prayer-wall was 'parallel' to the north-western wall of the Kaaba. Inevitably there were differences of opinion, and different directions were favoured by particular groups. Indeed, in each major region of the Islamic world, there was a whole spectrum of directions used for the qibla (see figure 7). Only rarely do the orientations of medieval mosques correspond to the qiblas derived by computation (see below). Recently some medieval texts have been identified which deal with the problem of the qibla in Andalusia, the Maghrib, Egypt, Iraq and Iran, and Central Asia. Their study has done much to clarify the orientation of mosques in these areas. In order that prayer in any reasonable direction be considered valid, some legal texts assert that while facing the *actual* direction of the Kaaba (*ayn*) is optimal, facing the *general* direction of the Kaaba (*jiha*) is also legally acceptable.

In various texts on folk astronomy, popular encyclopaedias and legal treatises, we find the notion of the world divided into sectors about the Kaaba, with the qibla in each sector having an astronomically-defined direction. Some twenty different schemes have been discovered recently in the manuscript sources, attesting to a tradition of sacred geography in Islam far more sophisticated than the corresponding Jewish and Christian notions of the world centred around Jerusalem.

The earliest schemes of Islamic sacred geography date from the ninth century, but the main contributor to the development of Islamic sacred geography was a Yemeni legal scholar named Ibn Suraqa, who studied in Basra about the year 1000. Ibn Suraqa devised three different schemes of sacred geography, with the world arranged in 8, 11 and 12 sectors around the Kaaba. Each sector of the world faces a particular section of the perimeter of the Kaaba. Simpler versions of his 12-sector scheme occur in the popular geographical works of Yaqut al-Rumi (*ca.* 1200) and al-Qazwini (*ca.* 1250) and the encyclopaedia of al-Qalqashandi (*ca.* 1400). From the fifteenth century to the nineteenth, we find a proliferation of schemes with different numbers of divisions between eight and 72 divisions of the world around the Kaaba; one rather spectacular example for a sixteenth-century Tunisian nautical atlas is reproduced as figure 8.

Muslim astronomers from the eighth century onwards concerned themselves with the determination of the qibla as a problem of mathematical geography. This activity

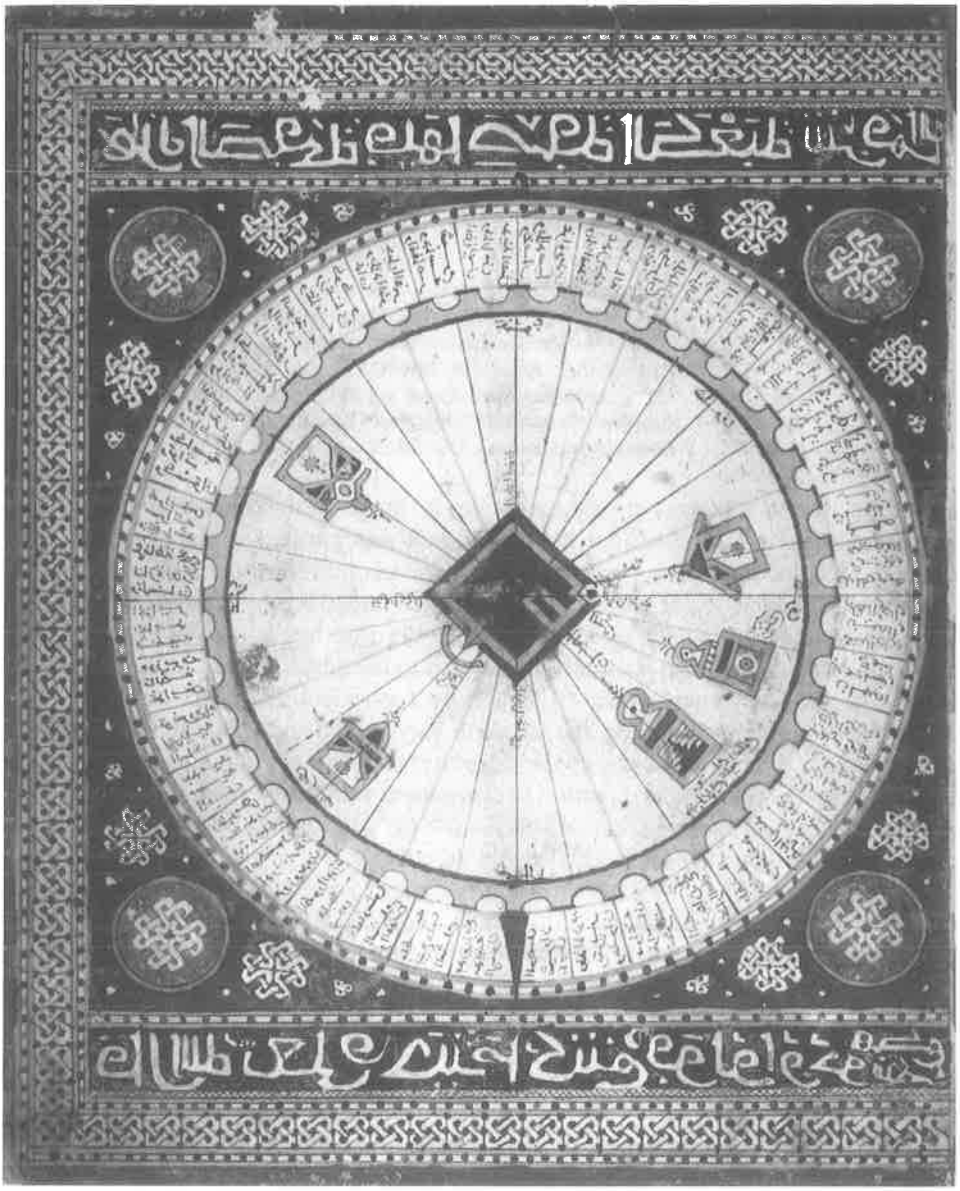


Figure 8. A late scheme of sacred geography in which localities all over the Islamic world are arranged around the Kaaba. Their positions are derived by tradition not by calculation and in many cases are not in accord with geographical reality. (Reproduced from MS Paris B.N.ar.2278 with kind permission of the Bibliothèque Nationale, Paris).

involves the measurement of geographical coordinates and the computation of the direction of one locality from another by procedures of geometry or trigonometry. The qibla at any locality was defined as the direction of Mecca along the great-circle on the terrestrial sphere. The basic problem, illustrated in figure 9, is to determine the direction of Mecca M from any locality X, given the latitudes of both localities measured by MB ($=b$) and XA ($=a$), and the longitudinal difference AB ($=c$). The qibla is measured by the angle AXM ($=q$).

Muslims inherited the Greek tradition of mathematical geography, together with Ptolemy's lists of localities and their latitudes and longitudes. Already in the early ninth century observations were conducted in order to measure the coordinates of Mecca and Baghdad as accurately as was possible, with the express intention of computing the qibla at Baghdad. Indeed, the need to determine the qibla in different localities inspired much of the activity of the Muslim geographers. The most important Muslim contribution to mathematical geography was a treatise by the eleventh-century scientist al-Biruni. His purpose was to determine for his patron the qibla at Ghazna (in what is now Afghanistan), a goal which he achieved most admirably.

Once the geographical data are available, a mathematical procedure is necessary to determine the qibla. The earliest Muslim astronomers who considered this problem developed a series of approximate solutions, all adequate for most practical purposes, but in the early ninth century, if not before, an accurate solution by solid trigonometry was formulated. The modern formula is rather complicated, namely:

$$q=\cot^{-1}\left(\frac{\sin a\cos c-\cos a\tan b}{\sin c}\right)$$

but the formulae derived by the Muslim astronomers from the ninth century onwards were mathematically equivalent to this. Muslim astronomers also compiled a series of tables displaying the qibla for each degree of latitude and longitude difference from Mecca based on both approximate and exact formulae, the first of these being prepared in Baghdad in the ninth century.

Over the centuries, numerous Muslim scientists discussed the qibla problem, presenting solutions by spherical trigonometry, or reducing the three-dimensional situation to two dimensions and solving by geometry or plane trigonometry. They also formulated solutions using calculating devices. But one of the finest medieval mathematical solutions to the qibla problem was reached in fourteenth-century

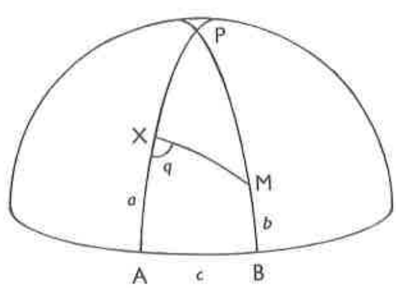


Figure 9. In this diagram, AB represents the equator and P the North Pole. It is required to find the direction of Mecca from any locality X. The latitudes of both localities are represented by MB and XA and their longitude difference by AB.

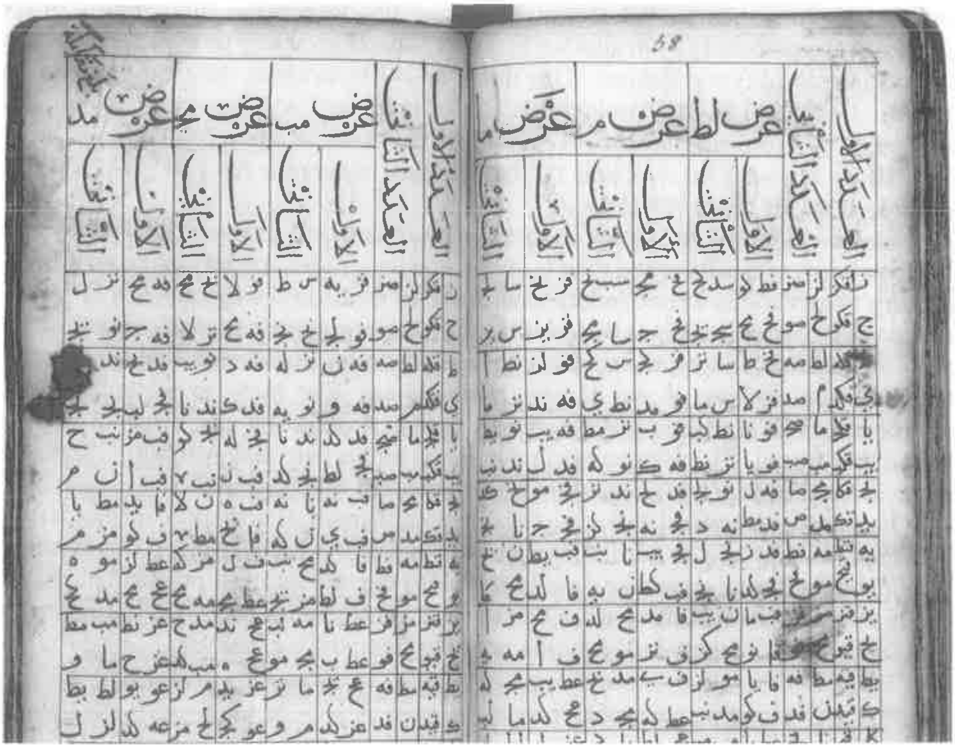


Figure 10. An extract from al-Khalili's table for finding the qibla. For each degree of latitude (here 39°, 40°,..., 44°) and each degree of longitude difference the qibla is given in degrees and minutes. The values are invariably accurately computed. (Reproduced from MS Paris B.N.ar.2558 with kind permission of the Bibliothèque Nationale, Paris).

Damascus: a table by al-Khalili displays the qibla for each degree of latitude from 10° to 56° and each degree of longitude from 1° to 60° east or west of Mecca, with entries correctly computed according to the accurate formula (see figure 10). This splendid table (rediscovered only in the early 1970s) was not widely known in later Muslim scientific circles. Muwaqqits, or professional mosque astronomers of later centuries, wrote treatises about the determination of the qibla but did not mention this Syrian table. By the fourteenth century the correct values of the qibla of each major city had long been established (correct, that is, for the medieval coordinates used in the calculations). Simple qibla-indicators fitted with a magnetic compass and a gazetteer of localities and qiblas became common, and the modern variety (see below) represents a continuation of this tradition.

Nevertheless, al-Khalili's table did not mark the end of serious Muslim activity in this field. In 1989 there was sold at Sotheby's in London a qibla-indicator, probably made in Isfahan about 1700, which bears a cartographic grid so devised that one can read qiblas directly off the map (see figure 11). Mecca is the centre of the grid and one has only to lay the diametrical rule over any city marked on the map (between Spain and China, Europe and the Yemen) to read off the qibla on a circular scale around the

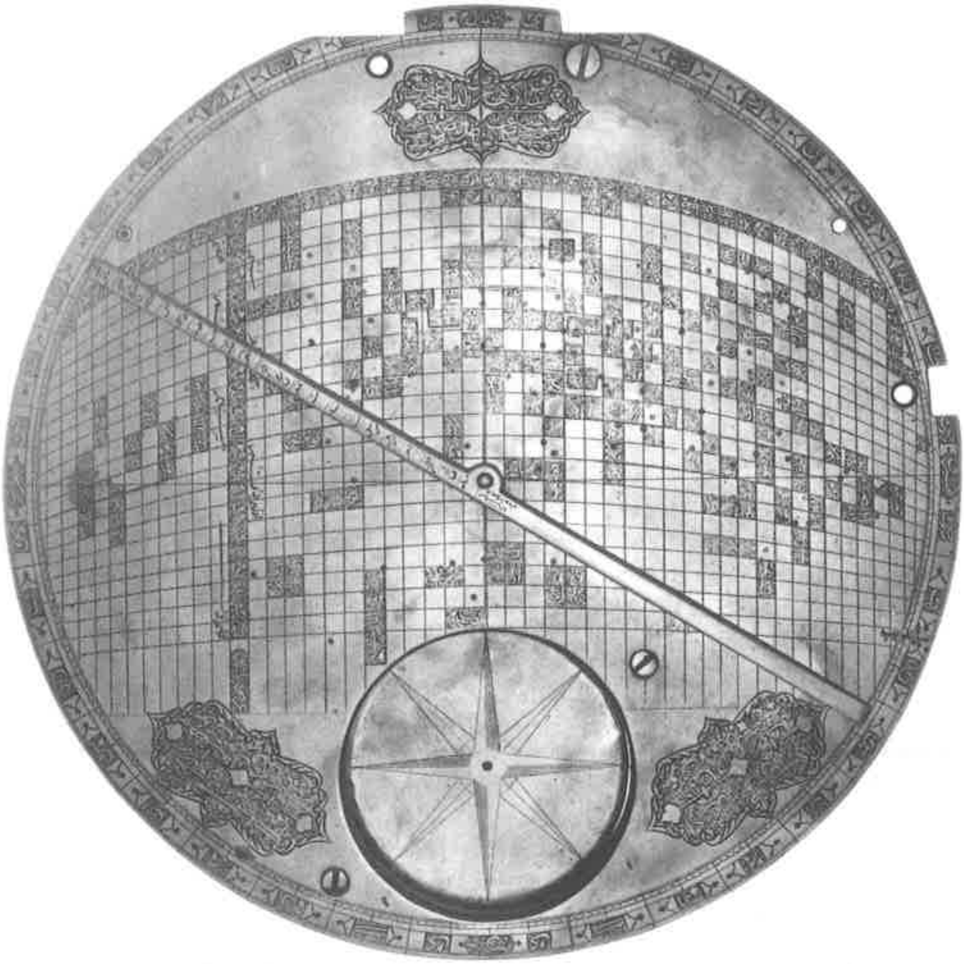


Figure 11. A spectacular cartographic grid for finding the qibla of any locality in the Islamic world. Mecca is situated at the centre, and the names of numerous localities are written alongside points which represent their geographical coordinates. The projection is so devised that the qibla can be read directly from the scale around the grid. (Courtesy of the owner.)

grid. So much for the achievements of the Muslim scientists in this single small area of their activities.

The alignment of medieval mosques reflects the fact that the astronomers were not always consulted on their orientation. But now we know from textual sources which directions were used as a qibla in each major locality, we can better understand not only the mosque orientations but also recognize numerous cities in the Islamic world that can be said to be qibla-oriented. In some, such as Taza in Morocco and Khiva in Central Asia, the orientation of the main mosque dominates the orientation of the entire city. In the case of Cairo (see figure 12) various parts of the city and its suburbs are oriented in three different qiblas. The new Fatimid city of al-Qahira, founded in the tenth century, faces winter sunset, which was the qibla of the Companions of the

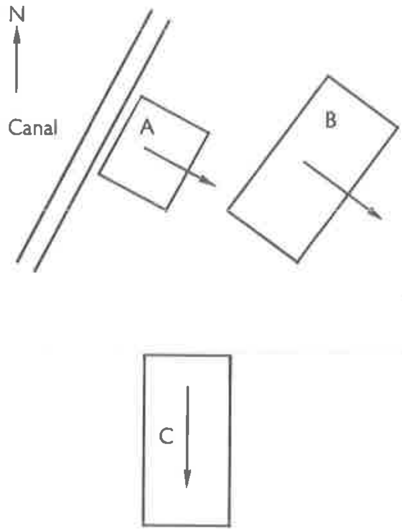


Figure 12. The main orientations of three parts of medieval Cairo. Each part is qibla-oriented, one (A) in the qibla of the Companions of the Prophet (winter sunrise at 27° south of east), another (B) in the qibla of the astronomers (at 37° south of east), and the third (C) in the qibla of the prophet when he was in Medina (due south).

Prophet who erected the first mosque in nearby Fustat some three centuries previously. The later Mamluk 'City of the Dead' faces the qibla of the astronomers. The predominant orientation of architecture in the suburb of al-Qarafa is towards the south, another popular qibla. The splendid Mamluk mosques and madrasas built along the main thoroughfare of the old Fatimid city are aligned externally with the street plan, and internally with the qibla of the astronomers: one can observe the varying thickness of the walls when standing in front of the windows inside the mosque overlooking the street outside.

This is an area of the history of urban development in the Islamic world which has only recently been studied for the first time, not least because, prior to the discovery of the textual evidence, it was by no means clear which directions were used as qiblas: even if a qibla at variance from the true qibla was clearly popular, it was not known why.

The first accurate longitude values of localities in the Islamic world become available only with the systematic scientific cartographic surveys of the eighteenth and nineteenth centuries. Thus most of the accurately-computed qiblas of the medieval astronomers could be judged as being in error by a few degrees anyway. But who are we to judge the 'accuracy' of any particular qibla?

Nowadays urban Muslims are content to use the qiblas found by calculation from modern geographical coordinates. In rural areas where there is no mosque nearby, astronomical horizon phenomena are still used for the sacred direction. In recent years, various devices for finding the qibla have appeared on the market, usually in the form of a magnetic compass with a list of directions for the qiblas of the major cities of the world. Some computerized prayer-clocks will purr when properly aligned with the qibla. Few who use such devices realize that they are heirs to a tradition going back over a millenium.

Other applications of science to daily life

There are two other topics which ideally merit inclusion in an article bearing this title, but which—not just for reasons of space—must be mentioned briefly. The first is the algebra of inheritance. The rules for the distribution of estates as formulated in the Koran are complicated, and their application involves some skill in arithmetic. Both the legal scholars and certain mathematicians wrote on this subject, but only two or three simple works by legalists have been studied and until recently no research of consequence had been conducted on the numerous available sources. There is also a vast corpus of literature on weights, measures and arithmetical techniques.

Secondly, the Muslims developed geometric designs for the decoration of religious architecture and also secular artefacts. The acceptability of such ornamentation is discussed by various legal scholars, but their writings have yet to be properly studied. Only two Muslim mathematicians are known to have included remarks on geometric design in their writings, a fact which confirms the suspicion that this was an art passed down amongst the practitioners. Some years ago a manuscript of an artisan's manual with guidelines for generating numerous patterns was discovered but it has yet to be published.

Concluding remarks

As we have shown, the legal scholars of medieval Islam used methods for regulating the calendar and prayer-times and for finding the the sacred direction which were simple and adequate for practical purposes. Their ingenuity in coping with differences of opinion never lost sight of the basic purpose of Koranic and Prophetic injunctions.

Some of the greatest of the Muslim scientists dealt with the calendar, prayer-times, and the qibla, and in these areas, as in others, their mathematical creativity and their quest for greater accuracy was impressive. In later centuries (after the thirteenth), competent astronomers were appointed to the staffs of major mosques in order to advise on these specific subjects. But the solutions developed by Muslim scientists were invariably too complicated for widespread application in the medieval milieu.

Although the scholars of the sacred law and the scientists proposed different solutions for the same individual problem, there are few records of serious discord between the two groups in the medieval sources. The legal scholars criticized mathematical astronomy mainly insofar as it was used by some as the handmaiden of astrology, which was anathema to them. The scientists seldom spoke out against the simple procedures adopted by the legal scholars.

Only through recent studies of the vast manuscript sources available for the further documentation of Islamic civilization have we come to appreciate the dual nature of science in Islam, and the ways in which it was applied in daily life. We now have a much better idea of the role of folk science in Islamic society, as well as a clearer understanding of the outstanding achievements of the Muslim scientists, which were remarkable in many respects and by no means restricted to the three areas which we have discussed here. The Islamic Near East, far more than any other religio-cultural area, witnessed truly remarkable developments in scientific research directed towards the requirements of religion. ■

To delve more deeply

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