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Chapter 29

Dusk and Dawn in Medieval Islam: on the Importance of Twilight Phenomena with Some Examples of Their Representations in Texts and on Instruments

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They asked the Prophet – God bless him and grant him salvation – which act is preferable to God: He said: Prayer at the right time […].[1]

Abstract. Dusk and dawn are one of the most important astronomical phenomenon used in Islamic ritual worship. They are connected with two of the five pillars of Islam, the fasting in Ramadan, and the ritual prayer. They are to be performed at the right time to be accepted. To know about dusk is necessary in Ramadan to determine the end of fasting, and about dawn to determine the beginning of fasting 'when a white thread may be distinguished from a black' (Sura 2,187). Further they are in need of determining three of the five daily ritual prayers in Islam, the evening prayer, the night prayer and the morning prayer. All of them are defined by twilight phenomena. These prayers rest on the Qur'an (see Sura 11,114, Sura 17,78 and Sura 50,39f) and the Sunna, the Hadith collections with the acts and sayings of the Prophet Muhammad. These collection contain different descriptions or definitions of these prayer times. Most of them are

[1] al-Bukhārī, 'Mawāqīt al-salāt, Fadl al-salāt li-waqtihā (no. 496)', in *'Abd Allāh Muhammad b. Ismā'īl: Sahīh (Le receuil des traditions mahométanes),* ed. M. Ludolf Krehl, continued by Th. W. Juynboll (Leyden: 1862-1908). On further passages with in part barely different wording see Arent Jan Wensinck et al., *Concordance et indices de la tradition musulmane*, 8 vols, 2nd edn (Leiden, New York, Cologne: 1992). Vol. 2, p. 160b, (l. 23ff).

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phenomenological, for example 'Do the morning prayer when the stars become indistinct!' (Malik, Muwatta', Wuqut al-salat, Wuqut al-salat (no. 6)).

According to their position in Islamic religious duties dusk and dawn were widely discussed in different medieval Islamic astronomical sources, in texts and on instruments. On the one hand, in an astronomical tradition often called mathematical, the definition of these prayer times by twilight phenomena lead to exact and approximative methods to calculate time and duration of twilight by the angle of the solar depression below the horizon. These values are represented in tables and on instruments, especially on astrolabes. On the other hand texts on time keeping and the determination of the Qibla, the sacred direction in Islam towards Mecca, not written for the astronomical expert and probably produced in a legal context, so called folk astronomical texts, deals with the time and duration of twilight in two different kinds.

First, there are rough approximative methods of determining the beginning, duration and end of dusk and dawn by the Lunar Mansions using them as a 'star clock'. Second, these texts contain detailed descriptions of the twilight phenomena in the morning and in the evening probably based on observations which are very useful to interpret the definitions given in the Hadiths.

These descriptions are a beautiful example of an astronomical phenomenon which influenced the ritual worship of one of the three great monotheistic religions.

Introduction

The duration of twilight – the time between sunset and nightfall, and the time between daybreak and sunrise – is of special importance in Islamic worship. This paper will show where this importance lies, and how it was treated in medieval times.[2]

The five pillars of Islam are fundamental to Islamic faith and Islamic worship. They comprise the profession of faith, the pilgrimage to Mecca, worship consisting in the form of the five daily ritual prayers, the fast in Ramadān, and alms-giving.[3] Two of these pillars are connected with twilight phenomena.

During fasting in Ramadān eating, drinking and sexual intercourse are forbidden by day, and allowed during the night until –as the Qur'ān says – 'the white thread of dawn appears to you distinct from its black thread'.[4]

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[2] For an overview cf. Wiedemann and King, 'Shafaḳ', in *The Encyclopaedia of Islam. New Edition*, 11 vols (Leiden: 1960-2002).

[3] Cf., for example, the article 'Rukn. 1. In Religious and Legal Usage', in *The Encyclopaedia of Islam. New Edition*.

[4] Sura 2,187, Abdullah Yūsuf 'Alī, trans., *The Meaning of the Holy Qur'ān*. 10th edn (Beltsville, MD: 2002). Cf. also Plessner, 'Ramadān', in *The Encyclopaedia*

But this paper will focus on prayer: the times of the five daily ritual prayers are astronomically defined.[5] The daytime prayers – the noon prayer *zuhr* and the afternoon prayer *asr* – are defined in terms of shadow lengths.[6] But the three other prayers – the evening prayer *maghrib*, the night prayer *'ishā'*, and the morning prayer *fajr* – depend on twilight phenomena.[7]

The standard times of these three prayers are the following: the evening prayer is performed after sunset, when the sun has disappeared beneath the horizon. The night prayer begins with the disappearance of the evening twilight, and ends after one third or one half of the night has passed. The morning prayer begins with the break of dawn, and must end shortly before sunrise. Prayer at sunrise is forbidden.[8] But there are exceptions – until today. For example the website of al-islam.com lists different methods of determining the night and the morning prayer in modern times.[9]

These definitions were not fixed during the time of the prophet Muhammad. They are rather the conclusion of an evolution starting with his daily practice of prayer and the Qur'ān.[10] Among other verses

of Islam. New Edition; and Berg (ed.), 'Sawm', in *The Encyclopaedia of Islam. New Edition.*

[5] Cf. for example King, 'Mīḳāt, 2. Astronomical Aspects', in *The Encyclopaedia of Islam. New Edition*, p. 27b; or Wiedemann and Frank, *Gebetszeiten*, 1926, p. 2.

[6] Cf. for example David A. King, 'A Survey of Medieval Islamic Shadow Schemes for Simple Time-Reckoning', *Oriens* 32 (1990): pp. 19–249 (p. 196f).

[7] Cf. for example Eilhard Wiedemann, 'Über Erscheinungen bei der Dämmerung und bei Sonnenfinsternissen nach arabischen Quellen, *Archiv für Geschichte der Medizin* 15 (1923): pp. 43–52 (p. 43f), who mentions the dependence on the morning and the evening prayer on twilight phenomena. Reprinted in Eilhard Wiedemann, *Gesammelte Schriften zur arabisch-islamischen Wissenschaftsgeschichte*, ed. Fuat Sezgin (Veröffentlichungen des Instituts für Geschichte der arabisch-islamischen Wissenschaften, Reihe B: Nachdrucke 1, 1–3) (Frankfurt: 1984), Vol. 2, pp. 1092–1100; Also reprinted in *Celestial Phenomena and Observations in Islamic Sources. Texts and Studies 3*, ed. Fuat Sezgin (Islamic Mathematics and Astronomy 72) (Frankfurt: 1998), pp. 229–38.

[8] Cf. for example King, 'Mīḳāt, 2. Astronomical Aspects', in *The Encyclopaedia of Islam. New Edition*, p. 27b f; Monnot, 'Salāt', in *The Encyclopaedia of Islam. New Edition*, p. 928b f; or David A. King, 'Astronomy and Islamic Society: Qibla, Gnomics and Timekeeping', in Roshdi Rashed (ed.) *In Collaboration with Régis Morelon: Encyclopedia of the History of Arabic Science*, 3 vols (London: 1996), Vol. 1, pp. 128–84 (p. 170f).

[9] See www.al-islam.com (08-18-2003) using the link 'Prayer Times' and then further to 'Calculation Methods Differences'.

[10] Cf. for example Wensinck, 'Mīḳāt, 1. Legal Aspects', in *The Encyclopaedia of Islam. New Edition*, p. 27a, King, 'Mīḳāt, 2. Astronomical Aspects', in *The*

concerning the ritual prayer and its time,[11] there is the important Sura which says: 'Perform the prayer at the sun's decline till the darkness of the night, and reading the Qur'ān during morning twilight'.[12] Also very significant in this context is another verse which says: 'Praise Your Lord before the rising of the sun and before its setting, for part of the hours of the night – praise Him, and at the two ends of the day!'[13] Yet another verse says: 'Praise Your Lord when you rise, and for a part of the night – praise Him, and at the retreat of the stars!'[14]

But all of these definitions are not specific and in fact more or less vague. Prayer has to be performed some time at the evening, during a part of the night, and in the morning.

But the Qur'ān is not the only source for the ritual law of Islam: it is also based on the Sunna, which represents the reported acts and sayings of the Prophet Muhammad.[15] These reports are called Hadīth. In these collections of Hadīth the performance and the times of the ritual prayer are further elaborated.[16]

In a well-known Hadīth is stated that the Archangel Gabriel visited Muhammad on two consecutive days and gave him instructions for performing the five daily prayers. Traditionally the time of prayer of the first day is taken for the beginning, the time of prayer of the following day for the end of the ritual prayer. In this Hadīth the evening prayer begins when the sun sets, and ends at the same time.[17] The night prayer begins when the evening twilight sets, and ends after the first third of the night

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Encyclopaedia of Islam. New Edition, p. 27b; or Monnot, 'Salāt', in *The Encyclopaedia of Islam. New Edition*, p. 926a f.

[11] For an overview see Monnot, 'Salāt, 1. In the K'ur'ān', in *The Encyclopaedia of Islam. New Edition*.

[12] Sura 17,80/78 (trans. pgs).

[13] Sura 20,130 (trans. following 'Alī, *Holy Qur'ān*), partly similar to Sura 11,114: 'Perform the prayer at the two ends of the day and at the approaches of the night' (trans. following 'Alī, *Holy Qur'ān*).

[14] Sura 52,48f (trans. following 'Alī, *Holy Qur'ān*).

[15] For an overview cf. Robson, 'Hadīth', in *The Encyclopaedia of Islam. New Edition*; and Juynboll and Brown, 'Sunna', in *The Encyclopaedia of Islam. New Edition*.

[16] Cf. Wensinck, 'Mīḳāt, 1. Legal Aspects', in *The Encyclopaedia of Islam. New Edition*, p. 27a.

[17] See below fn. 43.

has passed. The morning prayer begins when the morning twilight appears, and ends when the sun is almost (on the horizon).[18]

This is quite clear – but it is not the only Hadīth on the prayer times. There are a lot more, and a lot more definitions. Two of the six most common Sunni collections of Hadīth contain a special chapter on the prayer times,[19] three deal with this subject in general under the heading 'Prayer'.[20] The following overview lists examples of the definitions of the morning prayer given in these collections and is not intended to be complete. Sometimes more than one definition is combined in one Hadīth. For the evening and the night prayer similar definitions can be found.

The definitions of the morning prayer may be summarized in four categories:

1. Definitions by means of the position of the sun relating to the local horizon: 'from daybreak, as long as the sun does not rise',[21] 'as long as the upper part of the sun does not rise'.[22]

[18] Ahmad b. Hanbal, 'Musnad al-mukaththirīn, Musnad Abī Sa'īd al-Khudrī (no. 10819)', in *Musnad*, 15 vols (Cairo: 1949-1956); On further passages with in part barely different wording see Wensinck, *Concordance 4*, p. 99b, l. 44 and p. 101, l. 36; cf. also Wensinck, 'Mīḳāt, 1. Legal Aspects', in *The Encyclopaedia of Islam. New Edition*, p. 27b.

[19] al-Bukhārī, 'Mawāqīt al-salāt', in *Sahīh*; and Abū 'Abd al-Rahman b. Shu'ayb al-Nasā'ī, 'al-Mawāqīt', in *Sunan*, together with Jalāl al-Suyūtī, *Zahr al-rubā 'alā mujtaba*, 6 parts in 3 vols (Cairo: 1383/1964).

[20] al-Tirmidhī, 'al-Salāt', in *Sunan*; Abū Da'ūd, *Sunan*, 2 vols (Cairo: 1371/1952); and Muhammad b. Yazīd Ibn Mājah, 'al-Salāt', in *Sunan,* 2 vols (Cairo: 1372-3/1952-3; Muslim in his *Sahīh* – Abū al-Husayn b. al-Hajjāj Muslim, *Sahīh*, with the Commentaries of al-Ubbī and al-Sanūsī, 9 vols (Beirut: 1994) – has a chapter 'al-Salat', and a chapter 'al-Masājid wa-mawādi' al-salāt' where he deals with the prayer times.

[21] Inter alia Ahmad b. Hanbal, 'Musnad al-mukaththirīn min al-sahāba, 'Abd Allāh b. 'Amr b. al-'Ās (no. 6671), in *Musnad*.

[22] Muslim, 'al-Masājid wa-mawādi' al-salāt, Awqāt al-salawāt al-khams (no. 967)', in *Sahīh*.

2. Definitions by means of the morning twilight: 'when the morning twilight breaks',[23] 'when the morning twilight begins',[24] 'when the morning twilight shines or when the morning twilight gleames'.[25]
3. Further astronomical definitions: 'during the darkness of the night (before daybreak)',[26] 'when the stars become blurred'.[27]
4. Non-astronomical definitions: 'if someone recognizes his partner at table',[28] 'when eating and drinking is forbidden to whom is fasting'.[29]

The end of the morning prayer is defined in a similar way:

1. Definitions by means of the sun's position: 'when the sun rises',[30] 'when the sun is on the point of rising'.[31]
2. Definitions by the colours of the morning twilight phenomena: 'at the same time (the morning twilight) becomes yellow',[32] '(at the same time) it glowes at daybreak'.[33]
3. Non-astronomical definitions: 'until the sight is unrestricted'.[34]
So here in the Sunna, and not in the Qur'ān, we will find the first more detailed definitions of the evening prayer, the night prayer, and the morning prayer.

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[23] Inter alia Muslim, 'al-Masājid wa-mawādi' al-salāt, Awqāt al-salawāt al-khams (no. 969)', in *Sahīh*.
[24] Inter alia al-Nasā'ī, 'al-Mawāqīt, Ākhir waqt al-'asr (no. 510)', in *Sunan*.
[25] Ahmad b. Hanbal, 'Bāqī musnad al-mukaththirīn, Musnad Jābir b. 'Abd Allāh (no. 14011)', in *Musnad*.
[26] Inter alia al-Bukhārī, 'Mawāqīt al-salāt, Waqt al-maghrib (no. 527)', in *Sahīh*.
[27] Inter alia Mālik b. Anas, 'Wuqūt al-salāt, Wuqūt al-salāt (no. 5)', in *Muwattā'* (Cairo: 1348-9/1929-30).
[28] al-Bukhārī, 'Mawāqīt al-salāt, Waqt al- ẓuhr 'inda al-zawāl (no. 508)', in *Sahīh*.
[29] Abū Da'ūd, 'al-Salāt, Fī al-mawāqīt (no. 332)', in *Sunan*.
[30] al-Tirmidhī, 'al-Salāt, Mā jā'a fī mawāqīt al-salāt 'an al-nabī (no. 139)', in *Sunan*.
[31] Inter alia Ahmad b. Hanbal, 'Musnad al-mukaththirīn, Musnad Abī Sa'īd al-Khudrī (no. 108190', in *Musnad*.
[32] Inter alia Muslim, 'al-Masājid wa-mawādi' al-salāt, Awqāt al-salawāt al-khams (no. 969)', in *Sahīh*.
[33] Inter alia al-Tirmidhī, 'al-Salāt, Mā jā'a fī mawāqīt al-salāt 'an al-nabī (no. 140)', in *Sunan*.
[34] Inter alia Ahmad b. Hanbal, 'Bāqī musnad al-mukaththirīn, Musnad Anas b. Mālik (no. 12262)', in *Musnad*.

As mentioned briefly at the beginning in the Sunna we will find also several Hadīths which say: God accepts your prayer only when it is performed in the right manner and *at the right time*.[35]

These are the basic sources of Islamic worship connected with twilight phenomena, and these were one of the reasons for developing special methods for determining the beginning and end of morning and evening twilight.

The Two Astronomical Traditions

In medieval Islamic society there existed two astronomical traditions: on the one hand folk astronomy, which uses simple arithmetic methods and observation by the naked eye, written by astronomers as well as by experts in Islamic law or philologists, and transmitted in calendars, almanacs, and folk astronomical treatises, and on the other hand – and often better known – mathematical or scientific astronomy which uses sophisticated trigonometric methods and instruments, written by astronomers, and transmitted in scientific astronomical treatises, and in *zījes* – medieval Islamic astronomical handbooks with tables.[36]

In folk astronomical texts we find very detailed and elaborated descriptions of twilight phenomena. For example there is a short version written by the thirteenth century Yemeni scholar al-Asbahī, a legal expert, philologist, and grammarian.[37] He says:

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[35] See above.

[36] For an introduction cf. for example, Daniel Martin Varisco, 'Islamic Folk Astronomy', in Helaine Selin (ed.) *Astronomy across Cultures*. *The History of Non-Western Astronomy* (Dordrecht et al.: 2000), pp. 615–50; and David A. King, 'Mathematical Astronomy in Islamic Civilisation', in Helaine Selin (ed.) *Astronomy across Cultures. The History of Non-Western Astronomy* (Dordrecht et al.: 2000), pp. 585–613.

[37] Manuscript: Ibrāhīm b. al-Asbahī, ʿAlī al-Janadī: Kitāb al-Yawāqīt fī al-mawāqīt (Oxford: Bodleian Library, March 134, foll. 9a-52a). Cf. Petra G. Schmidl, 'Zur Bestimmung der Qibla mittels der Winde', in Peter Eisenhardt, Frank Linhard, and Kaisar Petanides (eds) *Der Weg der Wahrheit. Aufsätze zur Einheit der Wissenschaftsgeschichte*. Festgabe zum 60 (Hildesheim, New York: Geburtstag von Walter G. Saltzer, 1999), pp. 135–46 (p. 135f), this quote in the Oxford manuscript on fol. [37] a. The whole chapter is fully discussed in Petra G. Schmidl, 'Bearbeitung volkstümlicher astronomischer Abhandlungen aus dem mittelalterlichen arabisch-islamischen Kulturraum. Zur Bestimmung der Gebetszeiten und der Qibla bei al-Asbahī, Ibn Rahīq und al-Fārisī', in press.

> The first dawn rises at the quarter of the sky like a wolf's tail, the upper part narrow, the lower part broad. Below it there is the blackness of the night. The second dawn lies at the lowest point of the sky across (the horizon). With it there is the whiteness of daybreak.

It is common opinion that this 'first dawn' describes the zodiacal light, a faint pyramidal light along the ecliptic, especially seen in regions near the terrestrial equator.[38] If we compare this report to modern descriptions of the phenomenon, the zodiacal light really does look like a wolf's tail, and the 'second dawn' stretches across the horizon.[39] To distinguish first or false dawn and second or true dawn is important for performing prayer at the right time: during the false dawn prayer is forbidden, during the true dawn prayer is recommended.[40] So this description may be useful to find the right time for the morning prayer.

Another very common topic in folk astronomical texts is an approximate and simple method of timekeeping by the lunar mansions.[41] The lunar mansions divide the ecliptic in 28 more or less equal parts, analogous to the zodiacal signs which divide the ecliptic in twelve equal parts. The apparent yearly and daily rotation of the sun is represented by these lunar stations: About every 13 days the sun enters a new lunar

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[38] Cf. Eilhard Wiedemann, 'Über al Subh al kādhib (die falsche Dämmerung)', *Der Islam* 3 (1912): p. 195. Reprinted in Eilhard Wiedemann, *Gesammelte Schriften zur arabisch-islamischen Wissenschaftsgeschichte*. ed. Fuat Sezgin (Veröffentlichungen des Instituts für Geschichte der arabisch-islamischen Wissenschaften, Reihe B: Nachdrucke 1, 1-3) (Frankfurt: 1984), Vol. 2, p. 700. Also reprinted in *Celestial Phenomena* 3 (1998): p. 223.

[39] Cf. Marcel Minnaert, *The Nature of Light and Colour in the Open Air* (New York: 1954), p. 287ff.

[40] Cf. for example Eilhard Wiedemann and Josef Frank, 'Die Gebetszeiten im Islam', *Sitzungsberichte der Physikalisch-Medizinischen Sozietät zu Erlangen* 58 (1926): pp. 1–32 (p. 12). Reprinted in Eilhard Wiedemann, *Aufsätze zur arabischen Wissenschaftsgeschichte*, ed. Wolfdietrich Fischer, 2 vols (Collectanea 6) (Hildesheim, New York: 1970), Vol. 2, pp. 757–88. Also reprinted in: *Astronomical Instruments and Observatories in the Islamic World. Texts and Studies 8*, ed. Fuat Sezgin (Islamic Mathematics and Astronomy 92) (Frankfurt: 1998), pp. 97–128.

[41] Briefly mentioned for example in Miquel Forcada, 'Mīqāt en los calendarios andalusíes', *al-Qantara* 11, no. 1 (1990): pp. 59–69 (p. 63f); fully discussed in Schmidl, *Volksastronomische Abhandlungen*, to appear.

mansion – this is analogous to the sun entering every 30° a new zodiacal sign. Within this space of time of 13 days this method assumes that during the night which amounts to 12 hours 14 lunar mansions rise in the east, 14 lunar mansion sets in the west or 14 lunar mansion culminate – after 6⁄7 hour the following lunar mansion rises, sets or culminates.[42]

Under these conditions the lunar mansions can be used as a simple star clock. If $M_{A(a)}$ is the lunar mansion which rises together with the morning twilight – it is the heliacal rising and describes the Ascendent, the rising point of the ecliptic at that moment– then $M_{S(a)} = M_{A(a)} + 2$ will be the lunar mansion which rises together with the sun.

To explain the connection with the prayer times discussed above we have to go far back. Every prayer time – except sometimes the evening prayer – has to be performed within a space of time.[43] Within this period the second half is less preferable to God than the first – it is only the time of permissibility. Further the first half is called the time of preference, and it is divided in the time of favour – the first quarter – and the time of waiver of punishment – the second quarter. This view is rooted in the Qur'ān and the Sunna.[44] At the morning prayer the time of favour begins with the break of dawn, and the time of permissibility ends at sunrise.

Besides the two specific lunar mansions mentioned above – $M_{A(a)}$, which rises with the break of dawn, and $M_{S(a)}$, which rises with sun rise – al-Asbahī also defines a lunar mansion of morning shining $M_{T(a)} = M_{A(a)} + 1$. And he says: this is the lunar mansion which rises at the point of time when the middle of the morning prayer has come and the time of preference for the morning prayer ends.[45] Similar definitions could be found for the division of the evening and the night prayer. This method allows one to divide the time of the morning prayer into two parts, and to perform prayer in the half more pleasing to God (see Fig. 1).

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[42] Cf. Kunitzsch, 'al-Manāzil', in *The Encyclopaedia of Islam. New Edition*; furthermore Pellat, 'Anwā'', in *The Encyclopaedia of Islam. New Edition*.

[43] The evening prayer represents a special case among the five daily ritual prayers in Islam, because there are very detailed discussions if it is to perform at a specific point of time or in a specific space of time; cf. Edward S. Kennedy, *The Exhaustive Treatise on Shadows by Abū al-Rayhān Muhammad b. Ahmad al-Bīrūnī*. Translation and Commentary. 2 vols (Aleppo: 1976), p. 217.

[44] Cf. for example Abū 'Īsā Muhammad b al-Tirmidhī, 'al-Salāt, Mā jā'a fī al-waqt al-awwal min al-fadl (no. 157)', 'Īsā b. Sawra', *Sunan,* 2 vols (n.p.: 1937); furthermore Wiedemann and Frank, *Gebetszeiten*, p. 1f.

[45] In the Oxford manuscript on fol. 19b.

The duration of twilight is a function of the solar longitude and the terrestrial latitude. In the scientific astronomical tradition the determination of the beginning and of the end of twilight is a special case of solving the problem of determining the time by means of the solar altitude above – or rather below – the local horizon, a problem often dealt with in medieval astronomical treatises and represented on medieval astronomical instruments.[46]

Depending on the astronomer concerned, the angle of depression of the sun below the horizon varies at nightfall between 16° and 19°, at daybreak between 17°and 20°.[47]

	Nightfall	Daybreak
Habash (9th c.)	18°	18°
Ibn Yūnus (10th c.), al-Bīrūnī (10th/11th c.)	17°	18°
al-Qāyinī (10th/11th c.)	17°	17°
Ibn Mu'ādh (11th c.)	19°	18°
Cairo Corpus (10th-13th c.)	17°	19°
al-Mūsī (13th c.)	18°	18°
al-Marrākushī (13th c.)	16°	20°
al-Khalīlī (14th c.)	17°	19°

The *zījes*, medieval Islamic astronomical handbooks with tables, often contain a chapter on the duration of twilight.[48] The famous astronomer

[46] Cf. for example Wiedemann and King, 'Shafaḳ,' in *The Encyclopaedia of Islam. New Edition*, p. 180a; and, Edward S. Kennedy and Marie Louse Davidian, 'al-Qāyinī on the Duration of Dawn and Twilight', *Journal of Near Eastern Studies* 20, no. 3 (1961): pp. 145–153, reprinted in: Edward S. Kennedy et al., *Studies in the Islamic Exact Sciences*, eds Mary H. Kennedy and David A. King (Beirut: 1983), pp. 284–92.

[47] Cf. Wiedemann & King, 'Shafaḳ', in *The Encyclopaedia of Islam. New Edition*, p. 179b f; for further values cf. David A. King, 'Ibn Yūnus', Very Useful Tables for Reckoning Time by the Sun', *Archive for History of Exact Science* 10 (1973): pp. 342–49 (p. 366f), reprinted in David A. King, *Islamic Mathematical Astronomy* (London: 1986), article IX.

[48] For *zījes* in general cf. for example King and Samsó, 'Zīdj', in *The Encyclopaedia of Islam. New Edition*; or David A. King, Julio Samsó, and Bernard R. Goldstein, 'Astronomical Handbooks and Tables from the Islamic World (750-1900): An Interim Report', *Suhayl* 2 (2001): pp. 9–105.

Habash al-Hāsib, who wrote in ninth century Baghdad, begins a chapter in his treatise with a heading which says: 'Determination of the beginning of the morning twilight and the end of the evening twilight'. He goes on: 'If we want (to determine) the beginning of the morning twilight or the end of the evening twilight, we multiply the sine of 18 degrees with …'.[49]

Treatises of timekeeping compiled during the Middle Ages comprise tables for that purpose. An anonymous table, from tenth century Baghdad, and preserved in a manuscript now in Paris, mentions, besides other prayer times, in the heading the beginning of the morning twilight, and the end of the evening twilight. For every day of the month the Ascendent point of the ecliptic at the beginning of the morning twilight is tabulated (see Fig. 2). al-Khalīlī, the well-known astronomer from fourteenth century Damascus shows in his Damascene corpus of tables for timekeeping for each degree of solar longitude the duration of evening twilight and the duration of morning twilight.[50] Just as in the folk astronomical treatises mentioned above in the scientific tradition the difference between first and second dawn is taken into consideration: a table from thirteenth century Anatolia, preserved in a manuscript now in Cambridge, shows for each 6° of solar longitude the longitude of the Ascendant – the point of the ecliptic which is instantaneously rising over the horizon – at various times of day relating to the prayers. Two columns are titled 'false dawn' – the first dawn

[49] Manuscript: Habash al-Hāsib: al-Zīj (Berlin, Ahlwardt 5750 (We. 90)); Cf. on Habash for example Hartner, 'Habash al-Hāsib', in *The Encyclopaedia of Islam. New Edition*; or Edwards S. Kennedy, Paul Kunitzsch, and Richard P. Lorch, *The Melon-shaped Astrolabe in Arabic Astronomy* (Boethius 43) (Stuttgart: 1999), p. 8ff; cf. on his *zīj*, Edward S. Kennedy, 'Zij Survey', in *A Survey of Islamic Astronomical Tables* (Transactions of the American Philosophical Society. New Series 46:2 (Philadelphia PA: 1956; reprinted about 1990), p. 126f and p. 151ff; cf. on twilight King, Samsó and Goldstein, *Astronomical Handbooks and Tables*, 2001, p. 89; on the manuscript in Berlin, see W. Ahlwardt, *Die Handschriften-Verzeichnisse der Königlichen Bibliothek zu Berlin*. 17. Band: Verzeichnis der arabischen Handschriften. Band 5 (Berlin: 1893), p. 200ff, no. 5750; on the manuscript in Istanbul, see Max Krause, 'Stambuler Handschriften islamischer Mathematiker', *Quellen und Studien zur Geschichte der Mathematik* [...] , Abt. B 3 (1936): pp. 437–532 (p. 446), this quote from Berlin manuscript fol. 153a; reprinted in Fuat Sezgin (ed.), *Miscellaneous Texts and Studies on Islamic Mathematics and Astronomy* 8 (Islamic Mathematics and Astronomy 83) (Frankfurt: 1998), pp. 237–332.

[50] See for example King, 'Mīḳāt, 2. Astronomical Aspects', in *The Encyclopaedia of Islam. New Edition*, plate XI.5; cf. on al-Khalīlī, for example King, 'al-Khalīlī', in *Dictionary of Scientific Biography*, 16 vols (New York: 1970-80).

– and 'true dawn' – the second dawn (see Fig. 3).[51] These represent a much more sophisticated manner of dealing with twilight phenomena than in the folk astronomical examples mentioned above.

Representations of twilight on instruments, especially on astrolabes, follow a well-known method counting the depression angle above the horizon and using the opposite point of the ecliptic for the solar longitude.[52] The determination of the beginning of the morning twilight or the end of the evening twilight follows the same procedure as timekeeping by means of the solar altitude above the local horizon and taking the opposite point of the ecliptic for the solar longitude. For example, a plate of an astrolabe from eleventh century Andalusia with altitude circles for every five degrees has markings for the morning and the evening twilight at 18° above the horizon.[53]

Some astrolabes bear on their back special markings which allows one to read the duration of twilight as a function of solar longitude from the altitude scale. There is a twelfth century instrument from Isfahan by Muhammad b. Abī al-Qasīm, on which the duration of the morning twilight for latitude 32° is represented graphically (see Fig. 4).[54] Two other fifteenth century examples signed by Shams al-Dīn Muhammad ☒affār also for latitude 32° are now preserved in Oxford (see Fig. 5).[55]

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[51] These tables are analysed in David A. King, *The Call of the Muezzin* (Studies in Astronomical Timekeeping in Medieval Islam, I-VI, X-XII) (Leiden: in press).

[52] This method is well described by Ibn Yūnus, cf. King, *Very Useful Tables*, p. 366ff, and Carl Schoy, 'Geschichtlich-astronomische Studien über die Dämmerung', Naturwissenschaftliche Wochenschrift 14 (1915): pp. 209–14 (p. 212ff), reprinted in Carl Schoy, *Beiträge zur arabisch-islamischen Mathematik und Astronomie*, 2 vols, ed. Fuat Sezgin (Reihe B. Nachdrucke, Abteilung Mathematik 4) (Frankfurt: 1988), Vol. 1, pp. 89–94. Also reprinted in *Celestial Phenomena* 3 (1998): pp. 255–60.

[53] Cf. Robert T. Gunther, *The Astrolabes of the World*, 2 vols (Oxford: 1932; reprinted London: 1976), p. 253ff, esp. plate LX and Fig. 121.

[54] Cf. www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html (08-30-2003) using the link 'Provisional Table of Contents' and then further to 'Part 1: Early Eastern astrolabes (to ca. 1500)' and scrolling to '1.2.12 An astrolabe by Muhammad ibn Abi l-Qāsim al-Isfahānī al-Sālihānī dated 496 H (#122 - Florence MSS)'.

[55] Cf. www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html (08-30-2003) using the link 'Provisional Table of Contents' and then further to 'Part 1: Early Eastern astrolabes (to ca. 1500)' and scrolling to '1.4.17 Five instruments by Shams al-Dīn Muhammad Saffār'.

In these ways dusk and dawn are of special importance in Islamic worship. Starting with the Qur'ān and the Sunna, which reflect Muhammad's daily practice of prayer and the experience of the early Muslim community, there is a development of further elaboration of their definitions. Muslim scholars and astronomers produced particularly impressive solutions to the problem of determining the duration of twilight.

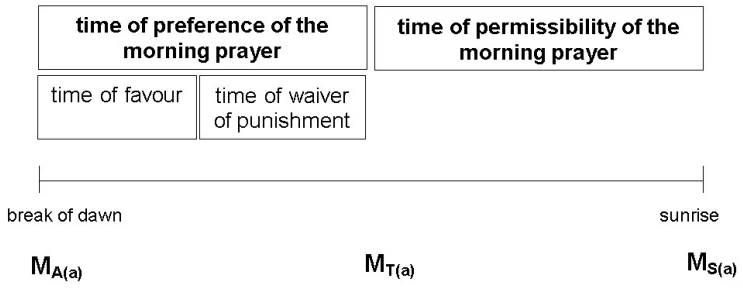

Figure 1. The time of morning prayer.

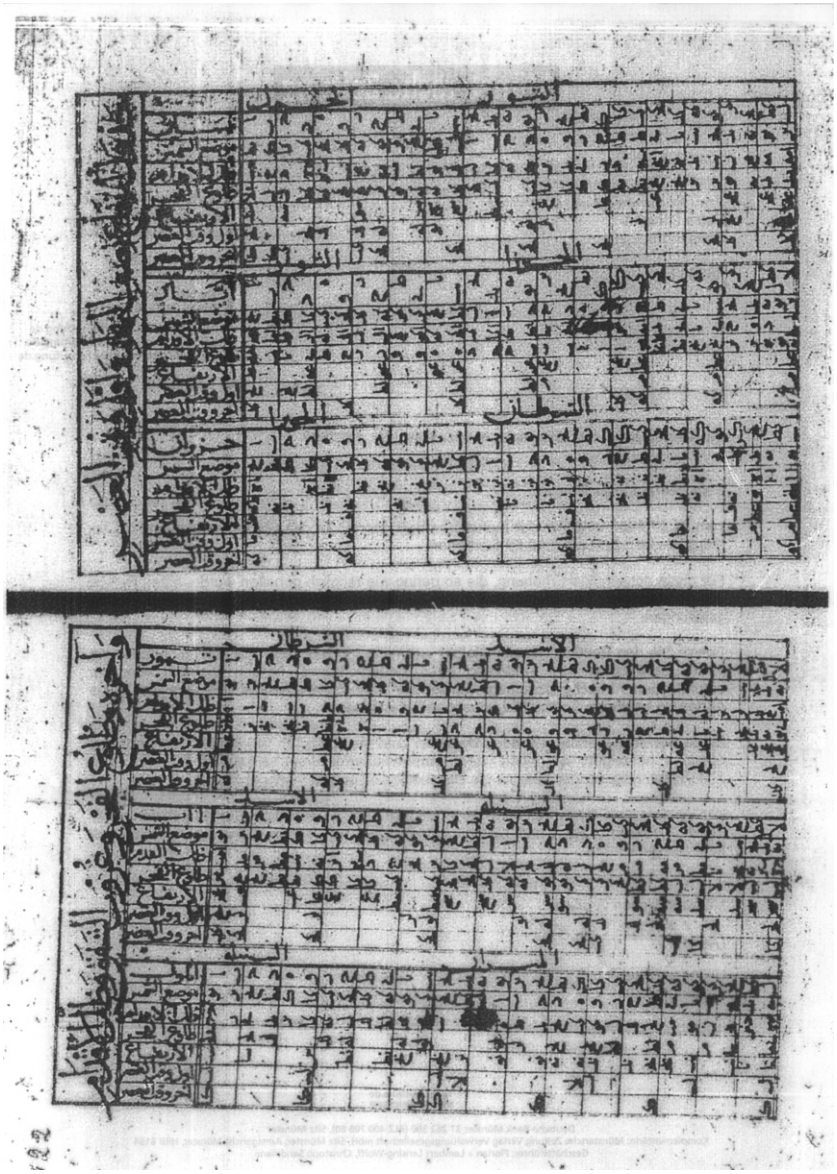

Figure 2. Anonymous prayer table, from tenth century Baghdad (courtesy of the Archive of the Institute for the History of Science, Frankfurt).

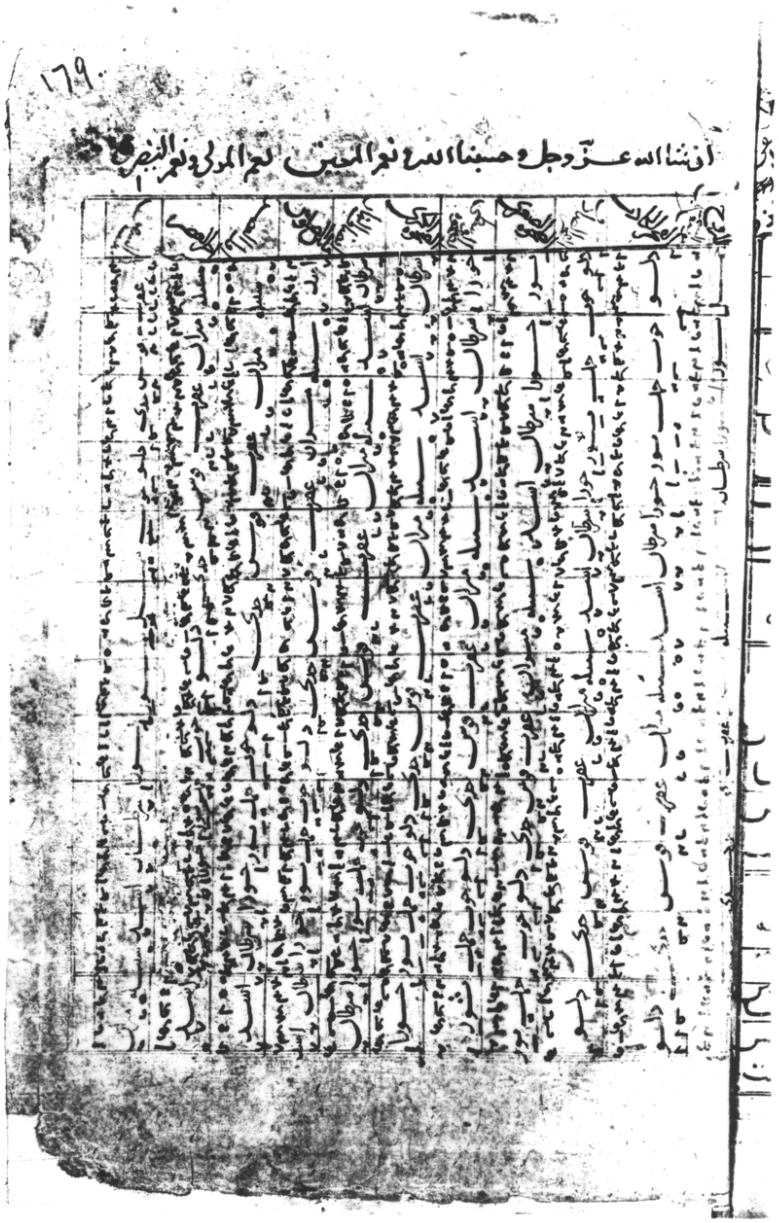

Figure 3. Thirteenth century prayer table from Thirteenth century Anatolia (courtesy of the Archive of the Institute for the History of Science, Frankfurt).

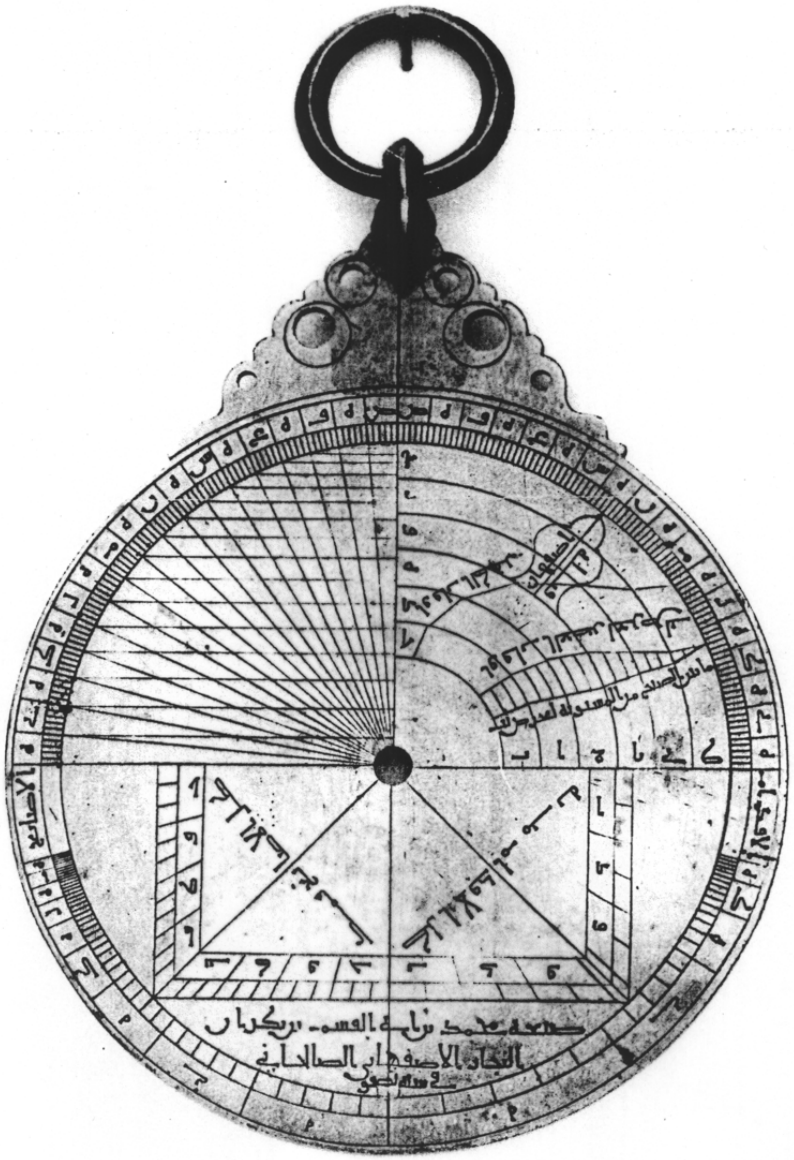

Figure 4. Astrolabe by Muhammad b. Abī al-Qasīm from twelfth century Isfahan (courtesy of the Archive of the Institute for the History of Science, Frankfurt).

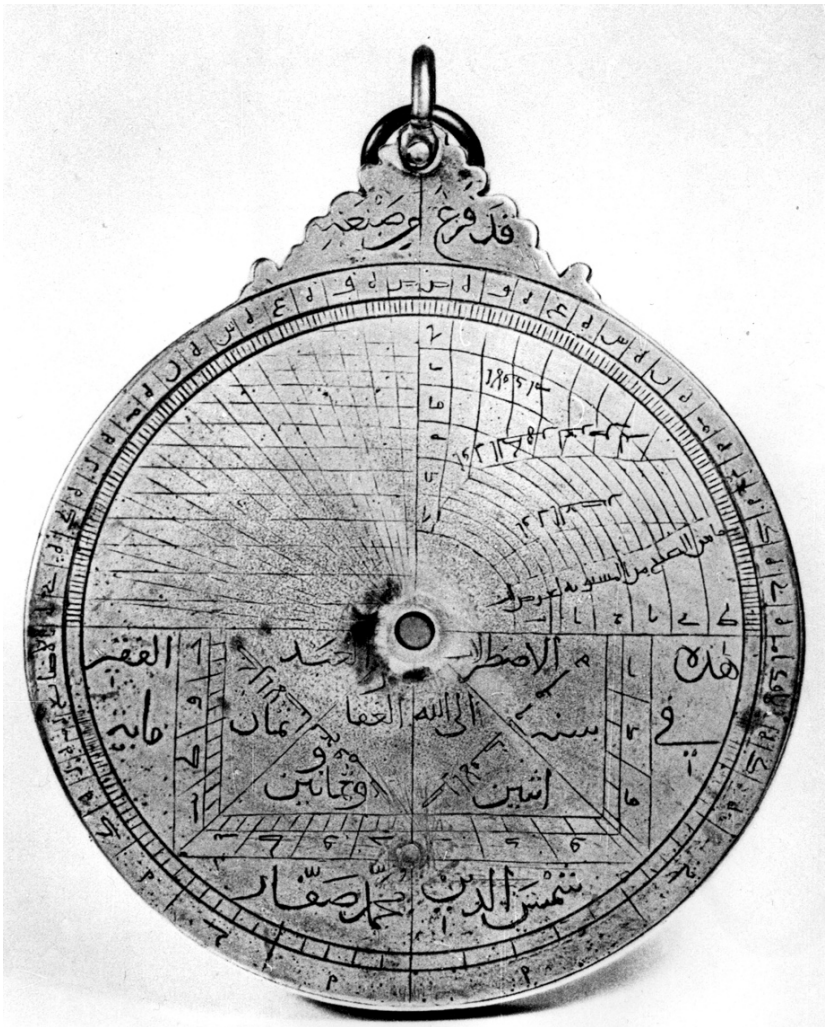

Figure 5. Astrolabe by Shams al-Dīn Muhammad ☒affār from fifteenth century Isfahan (courtesy of the Archive of the Institute for the History of Science, Frankfurt).