al-Ashraf ʿUmar's Tabṣira, *Chapter xxiii: Timekeeping at Night by the Moon in 13th-Century Yemen and Beyond*

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Abstract: This article explores methods for determining moonrise and moonset as evidenced within a range of pre-and early modern sources originating from Islamicate societies. The idea emerged during a workshop in July 2022 where a talk by the first author on Ibn Waḥshiyya's moonrise-moonset text in his *al-Filāḥa al-Nabaṭiyya* («The book of Nabatean agriculture») and the second author's project on the *Kitāb al-Tabṣira fī ʿilm al-nujūm* («Book of enlightenment in the science of the stars») by al-Ashraf ʿUmar revealed overlaps. Given the resemblances observed in the two sources, chapter xxiii of *Tabṣira* has been selected as the initial reference point for tracing the technique across additional sources. It is important to note that this examination does not assert comprehensiveness, nor does it account for the reciprocal interdependencies among the examples presented. Nevertheless, the present article suggests a categorisation of the diverse methods predicated on various factors such as exactitude, complexity, state of completeness, literary formats, and audience.

Keywords: al-Ashraf ʿUmar; *Tabṣira*, Ibn Waḥshiyya; *al-Filāḥa al-Nabaṭiyya*; timekeeping; Moon, calendars.

Resum: Aquest article explora els mètodes per determinar la sortida i la posta de la lluna, tal com s'evidencia en una sèrie de fonts premodernes i de l'inici de la modernitat provinents de les societats islàmiques. La idea va sorgir durant un taller el juliol de 2022, on una xerrada del primer autor sobre el text de la lluna i la posta de la lluna d'Ibn Waḥshiyya a *al-Filāḥa al-Nabaṭiyya* («El llibre de l'agricultura nabatea») i el projecte del segon autor sobre el *Kitāb al-Tabṣira fī ʿilm al-nujūm* («Llibre de la il·luminació en la ciència de

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les estrelles») d'al-Ashraf ʿUmar, va revelar superposicions. Donades les semblances observades a les dues fonts, s'ha seleccionat el capítol xxiii de *Tabṣira* com a punt de referència inicial per rastrejar la tècnica a través de fonts addicionals. És important assenyalar que aquest examen no afirma l'exhaustivitat, ni té en compte les interdependències recíproques entre els exemples presentats. No obstant això, el present article suggereix una categorització dels diversos mètodes basats en diversos factors com ara l'exactitud, la complexitat, l'estat d'exhaustivitat, els formats literaris i el públic.

Paraules clau: al-Ashraf ʿUmar; *Tabṣira*; Ibn Waḥshiyya; *al-Filāḥa al-Nabaṭiyya*; determinació del temps, lluna, calendaris.

1. Times and Calendars

A certain fascination with and also a necessity for using periodical heavenly phenomena to measure time is one of the fundamental characteristics of all human societies, which is also reflected in the rich heritage of pre-modern artefacts and manuscripts that have come down to us from Islamicate societies.[1] The apparent course of the Sun during the day and throughout the year, the apparent rotation of the fixed stars, and the phases of the Moon help in organising daily, monthly, and yearly activities, the former generally denoted as timekeeping, the latter two forming the fields of chronology and calendrics. How time was, and is, managed and perceived, is closely tied to the cultural characteristics of a society. The apparent orbit of the Sun and its position in the sky at specific times of the day organise, in Islamicate societies, the five daily prayers, an integral part of Islamic ritual norms and of significant social impact. For their determination, a variety of methods could be used, including shadow lengths, astronomical instruments, and mathematical calculations.[2] The lunar calendar based on the Moon's cycles plays a crucial role in Islamic religious practices, as it sets the rhythm of ritually significant events such as fasting in the month of *Ramaḍān* and pilgrimage in the month of *Dhū al-Ḥijja*.

1. For some noteworthy catalogues of Islamicate manuscripts and artefacts, see [no editors] 2005 (*L'age d'or des sciences arabes*); Porter, Tourkin and Vesel (eds) 2009; Maddison and Savage-Smith (eds) 1997.

2. For an introduction to timekeeping, chronology, and calendars in Islamicate societies, e.g., the following entries in *EI3*: «Astrolabes, quadrants, and calculating devices» by David A. King; «Timekeeping: socio-political and cultural aspects» by Avner Wishnitzer. Also the following entries in *EI2*: «*Ta'rīkh*» by Benno van Dalen; «*Mīḳāt*» by David A. King.

1.1 Timekeeping at Day

North of the tropic of Cancer, a terrestrial observer sees the Sun moving through the sky on a regular basis from its rising in the east through its culmination in the south to its setting in the west every day, allowing people to set times of day by tracking its route. Daily timekeeping by the Sun, i.e., using solar time, keeps track of the time based on the position of the Sun in the sky mainly by taking into consideration prominent phenomena such as end of dusk and break of dawn, sunrise, sunset, and its culmination or transit. In the pre-modern sources preserved from Islamicate societies, shadow schemes,[3] instruments, in particular sundials, but also astrolabes and quadrants,[4] data in *zīj*es,[5] and sets of tables inform about the regular motion of the Sun.[6]

1.2 Timekeeping at Night

It is understandable how much people in the past, who used to measure their time by looking into the sky during the day, wished for a similar pattern for the night sky when the Sun disappears. The fixed stars, usually learned through constellation patterns, provided a good tool to regulate the night-time. Similar to the Sun, they can be observed every night rising in the east, culminating in the south, and setting in the west. Using this apparent daily rotation to determine time at night is prevalent in many cultures, e.g., documented in the *ziqpu*-star lists from Ancient Mesopotamia, the earliest version of which are found in the MUL.APIN, an astronomical compendium of uncertain date, but composed probably before 900 B.C.[7] Another example is the nocturnal, an instrument that employs the movement of circumpolar stars with regard to the Pole Star, the first allusions to which appear in treatises

3. E.g., King 2004, vol. 1: 465–526 ; also the examples in Schmidl 2007, 256–259 (Arabic texts and German translations) and 322–325 with 572–573 and 622–625 (studies); Varisco 1994, 23–60 (Arabic text and English translations) and 88–89 (study).

4. See «*Mīḳāt*» in *EI*₂ by David A. King.

5. For details, e.g., King and Samsó 2001, 21–23.

6. E.g., King 2004, vol. 1: 247–298 (Cairene corpora of timekeeping) and 356–401 (Damascene corpora of timekeeping).

7. E.g., Steele 2014, 127; Rochberg 2004, 278; Hunger and Pingree 1999, 2 and 89; Hunger and Steele 2018, 1 iii 49–I iv 9, 138–141 and 186–190.

by Gerbert of Aurillac (d. 1003) and Ramon Llull (d. 1316).[8] Pre-modern sources from Islamicate societies, besides using tables, calculations, astrolabes, and other instruments,[9] also inform of a method for timekeeping at night by means of the lunar mansions,[10] that shows, by its very nature, many similarities to the star clocks of Ancient Egypt.[11]

2. Timekeeping at Night by Means of the Moon

The fixed stars can hardly be as eye-catching in the night sky as the Moon and its phases. Although its motion was predominantly used for calendrical purposes in the Islamicate world, the daytime hours being primarily determined with respect to sunrise, sunset, and the daily path of the Sun. It is an advanced problem ascertaining a regular monthly schedule of the rapid displacement of the Moon's apparent position in the sky, which would allow timekeeping at night by means of the Moon.

The initial motivation for writing this paper was to explore the historical and mathematical background of a method for timekeeping at night by the Moon presented in chapter xxiii of al-Ashraf ʿUmar's *Kitāb al-Tabṣira fī ʿilm al-nujūm* («Book of enlightenment in the science of the stars») written in 13th-century Yemen. In this article, it serves as a primary example for a textual and contextual analysis, supplemented by an edition of the Arabic text and its English translation, to survey a number of other examples from the Islamicate sources that make use of the lunar position for timekeeping at night. The sources inspected in this

8. Forcada 1995, 208–210. For an example in books, see Apian, *Instrumentbuch*, the chapter with the title «Das Vird Tayl, Das Ander Capittl von dem Rucken». For examples of surviving instruments, see, e.g., Ward 1981, 74–76 with plate xxviii.

9. For some examples of tables and calculations in *zīj*es, see Bagheri and Hosseinzadeh (eds) 2021, 163–168; al-Bīrūnī, *al-Qānūn al-Masʿūdī*, vol. 1: 486–489; of instruments, e.g., Charette and Schmidl 2004, 116, 141 and Hill 1981.

10. For some examples, see Schmidl, al-Ashraf ʿUmar's *Tabṣira*: Chapter xxx; Samsó 2008, 122–124; Schmidl 2007, 280–305 and 326–341 (Arabic texts and German translations), 602–614 and 628–637 (studies); Schmidl 2006, 78–85; Forcada 1995, 212–213; Ibn ʿĀṣim, *Kitāb al-anwāʾ*, 1993, 117–118; Forcada 1990, 59–64; Hehmeyer 2005, 89 with n. 6, n. 7, and n. 27; Nash and Agius 2011; Nash 2015; Varisco 1994.

11. Neugebauer and Parker 1960–1969, vol. I: 1–2 and 95–115, vol. II: 1–18; Leitz 2011; Leitz 1995, esp. 61–77 and 117–140; also Neugebauer 1955, 47–49 and 50–51; Symons 2020, 24–47; Depuydt 1998; Depuydt 2011.

article provide attempts in using the nocturnal motion of the Moon to measure the passing of the time at night through approximations, observational conventions, and mathematical relations. They are chosen from different places, times, and scholarly traditions, without making any claims either to exhaustiveness or to inclusiveness and vary in their exactitude and in their demand on their audience's skills and expertise. While acknowledging the presence of diverse scholarly traditions, this paper does not seek to comprehensively examine their intersecting aspects. Consequently, the exploration of such intersections remains an open question that necessitates further investigation.

2.1 Chapter xxiii of al-Ashraf ʿUmar's Tabṣira

Chapter xxiii of the *Tabṣira* provides an approximate method to determine the rising and setting times of the Moon. This treatise was written by al-Malik al-Ashraf (Mumahhid al-Dīn) ʿUmar b. Yūsuf b. ʿUmar b. ʿAlī b. Rasūl (d. 694/1296), the third of the Rasūlid sultans, a dynasty that ruled over Yemen from the 13th to the 15th century.[12] His political efforts are, however, eclipsed by his scholarly oeuvre that he developed most probably before his ascent to the throne.[13] It comprises more than ten treatises dealing with agriculture, astronomy, astrology, astronomical instruments, animal studies, genealogy, mantic practices, and medicine.[14] He also constructed at least six astrolabes, one still preserved, and possibly other instruments.[15]

In the Oxford manuscript, one of the two copies preserved,[16] this treatise consists of 50 chapters on various topics. Its objective can be roughly summarised as

12. E.g., «Rasūlids» in *EI*$_2$ by G. Rex Smith; Mahoney and Varisco 2021.

13. al-Khazrājī (ʿAsal and Redhouse) 1906, vol. 1, 236; for the life and oeuvre of al-Ashraf ʿUmar «Ashraf» in BEA by Petra G. Schmidl; see also Schmidl 2021a, 217–219 and tabsira.hypotheses.org and the literature mentioned there.

14. Schmidl to appear; see also Schmidl 2021a, 217–219.

15. For al-Ashraf ʿUmar's astrolabe preserved in New York (The Metropolitan Museum of Art, Accession number 91.1.535a–h) King 2005, study xiva, in particular 627–632 and www.metmuseum.org/art/collection/search/444408 – last accessed 2023-07-18. For his other astrolabes and instruments King 2005, study xiva, 643–646.

16. For manuscript Oxford, Bodleian Library, Huntington 233, see Uri 1787, 196–197, no. cmv and digital.bodleian.ox.ac.uk/objects/30f0365b-326a-4552-a446-809f0adf5c5c/ – last accessed 2023-05-02. For manuscript Paris, Bibliothèque nationale de France, arabe 2601.2, see Vajda

an endeavour to collect information needed in orientation in time and space and in predicting the future, presumably also to facilitate decision-making processes.[17] Chapter xxiii is only preserved in the manuscript in Oxford, most probably from 14th-century Yemen and therefore closer to the writing of the *Tabṣira* than the copy in Paris that dates to Muḥarram 1036/March 1626.[18] Its *editio princeps* followed by an English translation is given in the appendix of this article.

Chapter xxiii provides a simple arithmetical method to delineate the night hours based on the time between the rising and setting of the Sun and the Moon based on the point at which the Moon rises, or sets, every day as an almost constant difference from its rising, or setting, times the previous day. In the pre-modern world view with its geocentric cosmos, the daily or diurnal motion of all heavenly bodies is due to the uniform revolution of the celestial sphere, the first primary motion from east to west around an axis connecting its two poles. Conventionally, it takes the celestial sphere 24 hours for a full rotation of 360° around the earth. So, a seasonal hour is defined as one-twelfth of the length of day or night. The seven planets known to pre-modern observers, including the Sun and the Moon, have their own motions in the opposite direction, from west to east, inclined to the plane of the primary motion. Therefore, determining their daily positions in the sky depends on a number of factors, requiring the use of advanced mathematical relations (see also 2.6). The approximate method in the *Tabṣira* is based on two assumptions:

(1) The Moon orbits the earth once in each lunar month, which by definition in the Hijra calendar can be *complete* with thirty days or *incomplete* with twenty-nine days.
(2) Day and night are defined by the sunrise and sunset on the local horizon, so that each day and night have 24 seasonal hours, i.e., 12 hours in the day and 12 hours in the night.

1953, 647 and gallica.bnf.fr/ark:/12148/btv1b100375751/f189.item.r=Arabe%202601 – last accessed 2023-05-02. Edition, English translation, commentary, and study of al-Ashraf ʿUmar's *Tabṣira* is in preparation by the second author. For more information, including pre-prints of the chapters investigated so far, see tabsira.hypotheses.org and the literature mentioned there.

17. E.g., Schmidl 2021a.

18. See n. 16.

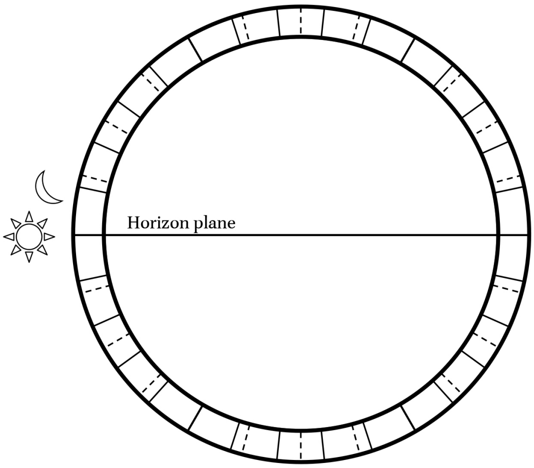


FIGURE 1. Divisions of the heavenly revolution into 24 hours (dashed lines) and 30 days (straight lines) of a complete month. Both sets of lines coincide every 5 days.

Assuming that the Moon has a uniform rotation co-axial with the primary motion of the universe, 24 hours are divided by the number of days in a lunar month in order to determine how many hours the Moon has progressed each day during its monthly cycle. The subsequent ratio will be $^{24}/_{30}$ or $^{4}/_{5}$ in a complete month of 30 days and $^{24}/_{28}$ or $^{6}/_{7}$ in an incomplete month of 29 days (see Tables 1 (a) and (b) as well as Fig. 1). Since, according to the text in chapter xxiii, it is assumed in the second case that the Moon is considered motionless on the 15th day, 28 days are counted in the calculation. By multiplying the days passed since the beginning of the month, the rising or setting times of the Moon relative to the sunset, the zero point of each night, are determined. In the *Tabṣira*, they are provided in two border- and frameless tables, for a complete and for an incomplete month, respectively, which is preceded by a recipe-like text that introduces the *rule to follow* and two examples (see Tables 1 (a) and (b) as well as the Appendix).

TABLE 1 (a): Moonrise and Moonset in the Nights of a Complete Lunar Month according to chapter xxiii of al-Ashraf ʿUmar's *Tabṣira* (h = hour[s]).

The days elapsed since the beginning of the month	Time at night when the Moon sets	The days elapsed since the beginning of the month	Time at night when the Moon rises
1	$^{4}/_{5}$ h	16	$^{4}/_{5}$ h

2	$1^{3}/_{5}$ h	17	$1^{3}/_{5}$ h
3	$2^{2}/_{5}$ h	18	$2^{2}/_{5}$ h
4	$3^{1}/_{5}$ h	19	$3^{1}/_{5}$ h
5	4 h	20	4 h
6	$4^{4}/_{5}$ h	21	$4^{4}/_{5}$ h
7	$5^{3}/_{5}$ h	22	$5^{3}/_{5}$ h
8	$6^{2}/_{5}$ h	23	$6^{2}/_{5}$ h
9	$7^{1}/_{5}$ h	24	$7^{1}/_{5}$ h
10	8 h	25	8 h
11	$8^{4}/_{5}$ h	26	$8^{4}/_{5}$ h
12	$9^{3}/_{5}$ h	27	$9^{3}/_{5}$ h
13	$10^{2}/_{5}$ h	28	$10^{2}/_{5}$ h
14	$11^{1}/_{5}$ h	29	$11^{1}/_{5}$ h
15	12 h	30	12 h

Table 1 (b): Moonrise and Moonset in the Nights of an Incomplete Lunar Month according to chapter xxiii of al-Ashraf ʿUmar's *Tabṣira* (h = hour[s])

The days elapsed since the beginning of the month	Time at night when the Moon sets	The days elapsed since the beginning of the month	Time at night when the Moon rises
1	$^{6}/_{7}$ h	16	$^{6}/_{7}$ h
2	$1^{5}/_{7}$ h	17	$1^{5}/_{7}$ h
3	$2^{4}/_{7}$ h	18	$2^{4}/_{7}$ h
4	$3^{3}/_{7}$ h	19	$3^{3}/_{7}$ h
5	$4\ ^{2}/_{7}$ h	20	$4\ ^{2}/_{7}$ h
6	$5^{1}/_{7}$ h	21	$5^{1}/_{7}$ h
7	6 h	22	6 h
8	$6^{6}/_{7}$ h	23	$6^{6}/_{7}$ h
9	$7^{5}/_{7}$ h	24	$7^{5}/_{7}$ h
10	$8^{4}/_{7}$ h	25	$8^{4}/_{7}$ h
11	$9\ ^{3}/_{7}$ h	26	$9\ ^{3}/_{7}$ h
12	$10^{2}/_{7}$ h	27	$10^{2}/_{7}$ h
13	$11^{1}/_{7}$ h	28	$11^{1}/_{7}$ h
14	12 h	29	12 h
15	at sunrise	–	–

2.1.1 Algorithmic Analysis of al-Ashraf ʿUmar's Method

The simple formula behind the method in chapter xxiii of the *Tabṣira* is structured in a logical step-by-step guide. For the sake of clarity for modern eyes, this *rule to follow*, or recipe, can be visually explained as follows (see Fig. 2).

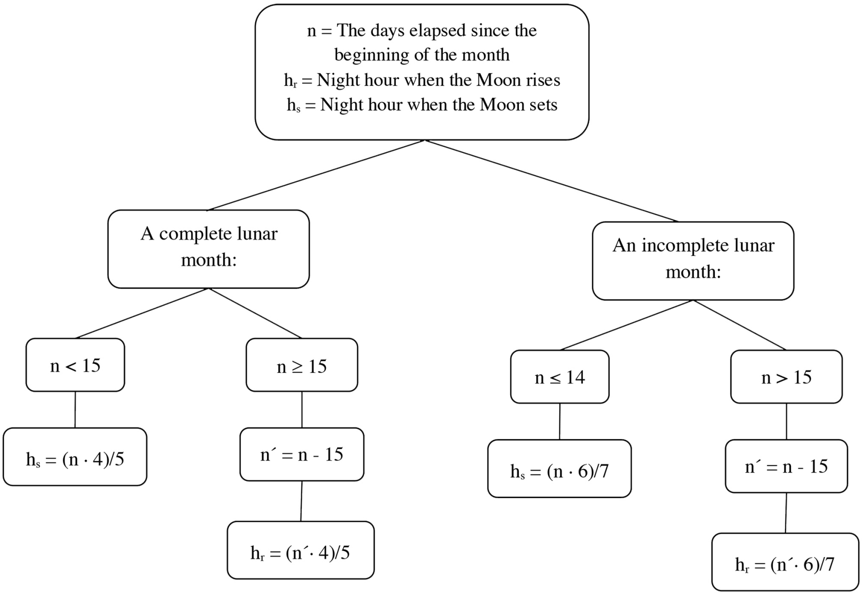


FIGURE 2. Algorithmic analysis of al-Ashraf ʿUmar's method (Note that the purpose of this diagram is only to display the mathematical procedure through visual aids without adapting standard symbols used in modern flowcharts).

As with most of the other chapters in the *Tabṣira*, al-Ashraf ʿUmar does not mention his sources in chapter xxiii. The method he presents is, however, not unique, again similar to many other chapters of the *Tabṣira*, where the author introduces well-known topics without referring to his sources.[19] It occurs in a number of pre- and early modern texts written in the Islamicate societies.

19. E.g., in chapter vi al-Ashraf ʿUmar deals with the terms, a common subject discussed in the astrological introductory literature (see Schmidl, al-Ashraf ʿUmar's *Tabṣira*: Chapter vi); in chapter xii he introduces metaphors describing a planet being in one of the twelve astrological houses that

2.2 *Examples in the* Anwāʾ *Literature*

Examples found in the *anwāʾ* literature bear strong resemblance to the method in chapter xxiii of al-Ashraf ʿUmar's *Tabṣira*. Although they are all derived from the same formula, the presentation of the methods differs. Some authors limit themselves to giving a recipe, mostly how to use the ratio $^6/_7$, and to providing a few individual examples without mentioning the values for all days of a month,[20] Others present the position of the Moon, day by day.[21] Judging by the available editions of these works, none of these examples arranges its data in a tabular form similar to the tables in chapter xxiii of the *Tabṣira*; its line-by-line structure also stands unique among them. The dominant form of presentation is continuous text without any visual layout except for calligraphic markings.

Another point of difference concerns mentions of the method's impreciseness. While some works on *anwāʾ*, similar to the *Tabṣira*, remain silent on the approximate nature of this method, others, such as the text by Abū Isḥāq Ibrāhīm b. al-Ajdābī (d. 650/1251),[22] even provide reasons for it:

ويغيب الهلال أوّل ليلة من الشهر لستة أسباع ساعة تمضي من الليل . ثمّ يتأخّر مغيبه كلّ ليلة مقدار ستّة أسباع ساعة حتّى يكون مغيبه في الليلة السابعة نصف الليل ، وفي ليلة أربعة عشر مع طلوع الشمس . وقد يتقدّم ذلك أحياناً ويتأخّر على قدر سرعة القمر وإبطائه ، وتمام الشهر ونقصانه . ثمّ يتأخّر طلوعه ليلة خمسة عشر مقدار ستّة أسباع ساعة ويزيد تأخّره مثل ذلك حتّى يكون طلوعه ليلة إحدى وعشرين نصف الليل .

The crescent sets on the first night of the month when six sevenths of an hour have passed since the night. Then, its setting is delayed every night by six sevenths of an hour until it sets on the seventh night at midnight, and on the fourteenth night at sunrise. This may sometimes precede and delay depending on the speed of the Moon as

are most probably taken from the Ikhwān al-Ṣafāʾ's epistle *On Astronomia* without saying so (see Schmidl, al-Ashraf ʿUmar's *Tabṣira*: Chapter xii).

20. E.g., Ibn Qutayba, *Kitāb al-Anwāʾ*, 129–130; ʿAbdallāh al-Thaqafī, *al-Anwāʾ wa-l-azmina*, 29; Ibn al-Ajdābī, *al-Azmina wa-l-anwāʾ*, 88.

21. E.g., Abū ʿAlī al-Marzūqī, *Kitāb al-Azmina wa-l-amkina*, 485, who does not detail the second half of the month and instead explains that the values in the two halves of the month are symmetrical.

22. Arabic text according to the edition in Ibn al-Ajdābī, *al-Azmina wa-l-anwāʾ*, 88; English translation by the first author.

well as the completeness and incompleteness of the month. Then, its rising is delayed on the fifteenth night by six sevenths of an hour, and its delay increases by the same amount until it rises on the twenty-first night at midnight.

2.3 Examples in the Filāḥa *Literature*

A technique similar to that in chapter xxiii of al-Ashraf ʿUmar's *Tabṣira* and the books on *anwāʾ* also appears in a number of agricultural texts, e.g., in the *al-Filāḥa al-Rūmiyya* («[Eastern] Roman Agriculture»; also known as *Kitāb al-Zarʿ*). Two Arabic translations have been recognised of this sixth century Greek text the original version of which is lost – one by Qusṭā b. Lūqā (fl. 3rd/9th c.) and one issued in the name of Cassianus Bassus Scholasticus (Qasṭūs b. Iskūlastīqa [6th c.]).[23] The two available editions of these translations display considerable differences, including their discussions of the rising and setting times of the Moon. A recipe for the successive use of the fraction $^6/_7$ in agreement with the nights of an incomplete lunar month appears only in Qusṭā b. Lūqā's text and is described devoid of any accompanying list or table,[24] whilst the other translation presents only a list of monthly times that do not increase linearly.[25]

Another example occurs in the *Kitāb al-Filāḥa al-Nabaṭiyya* («The book of Nabatean agriculture») by Abū Bakr Aḥmad b. Waḥshiyya (fl. late 3rd/9th, early 4th/10th c. [?]), a treatise that claims to be a translation from most probably Syriac into Arabic and is presumably based on earlier Ancient Mesopotamian sources, whose author, origin, and text history are still the subject of discussions.[26] The chapter with the heading *Bāb maʿrifat ayy al-awqāt yakūnu al-qamar fawqa al-arḍ matā yaṣiru sāʾiran taḥtahā* («Chapter on the knowledge at whatever times

23. See the texts in the editions by Wāʾil ʿAbd al-Raḥīm Aʿubayd of Qusṭā b. Lūqā, *al-Filāḥa al-Rūmiyya* and by Būrāwī al-Ṭarābulsī of Qastūs b. Iskulastiqa, *Kitāb al-Zarʿ*. See also the summary in Shopov 2019, 557 and the literature mentioned there.

24. Qusṭā b. Lūqā, *al-Filāḥa al-Rūmiyya*, 108–109.

25. Qastūs b. Iskulastiqa, *Kitāb al-Zarʿ*, 45–46.

26. See Hämeen-Anttila 2006, 3–33, in particular 10: «Despite the work done on the *Nabatean Agriculture*, it seems that the situation has remained unclear and the scholarly world is hardly unanimous on the date, original language and provenance of the work.» See also the summary in Schmidl 2021b, 214.

the Moon is above the Earth until it becomes moving below it») mentions the rising and setting times of the Moon in each night of a complete lunar month in a textual scheme followed by a paragraph focussing on the terms used in the previous part.[27] Unlike al-Ashraf ʿUmar, Ibn Waḥshiyya refers to the source of his data, namely two unidentified «Canaanite astronomer-astrologers» (*al-Kanʿānī al-munajjimān*), Ṣardāyā and Ṭāmīra.[28] Further differences concern the data provided. While the *Tabṣira* explains the method to determine the rising and setting times of the Moon, distinguishes between incomplete and complete months, and uses a fixed ratio for each of them, namely $^4/_5$ h and $^6/_7$ h, respectively, the *al-Filāḥa al-Nabaṭiyya* refrains from dealing with the underlying procedure; the setting and rising times of the Moon provided do not increase linearly, similar to the information in the *al-Filāḥa al-Rūmiyya* issued in the name of Qasṭūs b. Iskūlastīqa.[29] Given similar discussions in non-Islamicate literature on agricultural knowledge,[30] the possibility of cross-cultural exchanges through this path seems very likely; an observation that calls for deeper studies.[31] To an entanglement of traditions that cross linguistic boundaries also points a similar method of timekeeping by the Moon discussed in a chapter of the Syriac «Book of Medicines», a treatise «allegedly copied in 12th century», but «preserved only in late manuscripts».[32] It uses, however, a fraction different to all the Arabic examples presented in this article; this chapter and its relation to the Islamicate tradition deserves further research.

27. See the text in Toufic Fahd's edition of Ibn Waḥshiyya, *al-Filāḥa al-Nabaṭiyya*, vol. 1: 241–243.

28. Ibn Waḥshiyya, *al-Filāḥa al-Nabaṭiyya*, vol. 1: 243. Recent studies have raised serious doubts on the author's claim to have presented Nabatean knowledge. For a recent review of these studies, see Toral 2022, 380–382.

29. See n. 25.

30. Two examples are Pliny (the Elder), *Natural History*, vol. 5: 391; Cassianus Bassus, *Geōponika*, vol. 1: 12–15.

31. Some aspects of Ibn Waḥshiyya's lunar scheme is recently investigated in a presentation by Razieh S. Mousavi under the title «Moonrise, Moonset, and Night-Time Delineation» in the workshop «When the Stars Tell Time: Astronomical Timekeeping Practices at Night in Comparative Perspective», organised by Petra G. Schmidl and Sarah Symons, 7, 11, 14 July 2022 (virtually).

32. Schmidl 2022, 255 with n. 18–19. For an English translation Wallis Budge 1913, here vol. 2, 531; for a German translation Rudolf 2018, here 211.

2.4 *Moonrise and Moonset in* ʿilm al-mīqāt *Literature*

2.4.1 Al-Bakhāniqī' Text

In addition, the method used in chapter xxiii of al-Ashraf ʿUmar's *Tabṣira*, and less complete and differently presented also in books on *anwāʾ* and *filāḥa*, is found in texts on *ʿilm al-mīqāt* («science of reckoning times»), e.g., in the treatise *Kitāb al-Risāla fī al-muqanṭarāt wa-l-mujayyab wa-ghayrihi* («Book on almucantars, sines, and others») by Aḥmad b. Muḥammad al-Bakhāniqī (d. 755/1355), extant in a single manuscript in Berlin.[33] The author was related to the court of the Rasūlid Sultan al-Mujāhid ʿAlī (r. 721–764/1322–1363), a nephew of al-Ashraf ʿUmar, and wrote several treatises on astronomy and astronomical instruments, among others, he prepared time-keeping tables for Cairo.[34] Being called al-Azharī in some sources, suggests that he might be connected to the Azhar Mosque. The interest of Yemeni scholars in the Egyptian astronomical traditions has been emphasised in recent studies.[35]

In his treatise, al-Bakhāniqī addresses the question of the rising and setting times of the Moon along with other approximate formulae on *ʿilm al-mīqāt* followed by mentioning the names of the twenty-eight lunar mansions.[36] He considers twenty-eight days in a lunar month and then mentions the visibility times of the Moon, day by day, therefore only including half of the *Tabṣira*'s method, namely the part for the incomplete lunar months. Further, while both methods are alike in technique, the form of presentation differs between the two works. While the *Tabṣira* provides, in the Oxford manuscript, an introductory text followed by two tables, one for the incomplete and one for the complete lunar month with the nights rubricated and writing all numbers as numerals (see in the Appendix), al-Bakhāniqī's text in the Berlin manuscript is not arranged as a table. Rather the number computed for each day is written in red-inked *abjad* letters within the

33. For manuscript Berlin, Staatsbibliothek Preußischer Kulturbesitz, Sprenger 1835, see Ahlwardt 1893, 264–266, no. 5860 and ismi.mpiwg-berlin.mpg.de/witness/303133 – last accessed 2023-05-03.

34. On his tables for timekeeping in Cairo, see King 2004, 44–49 and 290–295. For more on his life and career, see King 2004, 251–252.

35. King 2005, 654–657.

36. Sprenger 1835, fol. 11a-12a. King 2004, 228–229 refers to the existence of a moonrise-moonset regulation in al-Bakhāniqī's text but does not describe the method in detail.

flow of the text. In other words, the numerical value is highlighted to function as a catchword, not the day of the month as is the case with the *Tabṣira*. The numbers given are in fact products of six (see Table 2).

Table 2: The values provided in al-Bakhāniqī's text (in the Berlin manuscript).

Day of the month	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Products of 6	و	يب	يج	كد	ل	لو	مب	مح	ند	س	سو	عب	عح	فد
	6	12	18	24	30	36	42	48	54	60	66	72	78	84

To obtain the time of moonrise or moonset each day, the assigned number has to be divided by seven; the result will be the hours and the remainder will be the minutes. It gives moonset in the first half of the month (day 1–14), and moonrise, in the second half (day 15–28). For instance, for the third day, the table provides the number «18», that means the Moon sets at $18 : 7 = 2 + {}^{4}/_{7}$ hours; or for the 27th day one finds «78», that means the Moon rises at $78 : 7 = 11 + {}^{1}/_{7}$ hours (see also 2.5.1).

Al-Bakhāniqī's text does not say anything specific about the application of this data for determining the prayer times. The fact that its author was related to the court of al-Mujāhid ʿAlī, who followed his father, al-Muʾayyad Dāʾūd (r. 696–721/1296–1322), a brother of al-Ashraf ʿUmar, on the throne, makes it likely that he might have had access to the *Tabṣira* among other works and adds to the importance of his text. To establish a dependency, however, requires further research.

2.4.2 Ibn Ṭūghān al-Qiṭṭajī's Table

Further, in his extensive study on *ʿilm al-mīqāt* mainly based on hitherto unpublished manuscripts from Islamicate societies, David A. King has come across only one relatively late moonrise table, which he calls «unique».[37] As he shows, Jamāl al-Dīn Yūsuf b. Ṭūghān al-Qiṭṭajī (fl. 10th/16th c.), known as al-miqātī («the timekeeper») in his time, calculates the difference between sunset and moonset from the nocturnal arc and the days elapsed since conjunction, admitting that the method is

37. King 2004, 317.

approximate. According to the accompanying description of the table, King suggests the following relation as the formula behind the data in the table:

$$f = \eta \cdot \frac{2N}{180} \cdot n$$

where 2N is the nocturnal arc (*qaws al-layl*), η the mean daily relative motion of the Sun and the Moon (here 12;53°, according to King's assumption), and n the number of days passed since the beginning of the month. When greater than 14 days, the instruction requires the user to subtract 14 and insert the remainder in the equation instead. While for the first half of the lunar month the table provides the time interval between sunset and moonset, for the second half the difference between sunset and moonrise is given.

The description does not refer to any sources, nor is there any direct reference to the times of prayers. The procedure, however, is dissimilar to previous methods and is a more accurate approach. Whether al-Qiṭṭajī's table was an attempt to simplify a complicate procedure as appears, e.g., in *zīj*es (see 2.6) or vice versa, to make an approximate method more precise, requires further investigation.[38]

2.5 Rising and Setting Times of the Moon in the Astrolabe Literature

The most popular device *per se* for timekeeping at night in pre-modern Islamicate societies is the astrolabe that models the heavenly revolution. It enables its user to know the time, provided the astrolabe plate is set for the latitude of the location, by rotating the rete appropriately, since a given star rises at the desired time.[39] Accordingly, the subject of the rising and setting times of the stars is discussed, as a key subject, in treatises on the astrolabe. However, determining the times of moonrise and moonset has so far not been attested on any instrument,[40] but is addressed in some astrolabe treatises. The method is, however, different to the approximate

38. Investigating possible sources of the mathematical data in al-Qiṭṭajī's table is the subject of an article in progress by the first author in collaboration with Richard L. Kremer.

39. There is an ever-growing literature in print and online on the construction and use of the astrolabe, a concise summary is still North 1974.

40. Cf. King 2005, 369: «Then there are features mentioned in texts that are alas not attested on any surviving instruments. [...] Solar-lunar scales for calculating moonrise and moonset [...]).»

methods introduced in this article, as can be easily demonstrated by summarising one example.

The Syriac treatise on the astrolabe by Severus Sebokht (d. 667) includes a paragraph on how to find the time at night by means of the Moon. Although not explicitly stated, first the ecliptic longitudes of the Moon and the Sun have to be determined, e.g., by using a table, and marked on the rete of the astrolabe. Then the altitude of the Moon above the local horizon is measured by means of the alidade and the altitude quadrant on the back. Next, the marker of the Moon on the ecliptic circle of the rete is set on the appropriate altitude circle on the plate that fits to the place of observation; the marker of the Sun now allows the desired time to be read off.[41]

2.5.1 al-Khwārazmī

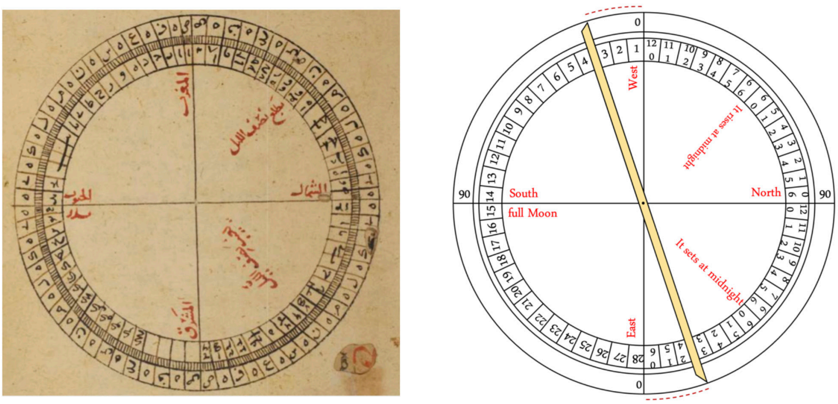
The texts attributed to al-Khwārazmī as part of his astrolabe book, are probably the earliest texts in Arabic that include this discussion. In addition to presenting methods using the standard plates of an astrolabe,[42] a stand-alone plate for determining moonrise and moonset is also introduced that is not designated to a specific geographical latitude.[43] According to the description and the accompanying diagram in the Berlin manuscript, the plate is divided into four equal parts by two diameters, whose radii indicate the four directions of the compass, namely north, south, east, and west.[44] In the outermost ring, each quadrant is divided into 90° in boxes of five degrees followed by strokes representing each single degree, that show the longitudinal distance between the Moon and the Sun. Each half of the innermost rim is divided into 28 boxes. The divisions on the left, or southern, side are labelled from 1 to 28 representing the days of a lunar month and are related to

41. Severus Sebokht, *Le traité sur l'astrolabe plan*, 243–244 (Syriac text) and 278 (French translation); for an English translation based on the French version, see Margoliouth 1932, 90.

42. Charette and Schmidl 2004, 123–124 (Arabic text), 149–150 (English translation), 172 (commentary).

43. Charette and Schmidl 2004, 126–127 (Arabic text), 152–153 (English translation), 175–176 (commentary).

44. For manuscript Berlin, Staatsbibliothek Preußischer Kulturbesitz, Landberg 56, see Ahlwardt 1893, 226–227, no. 5790 and 227, no. 5793; for more details, see Charette and Schmidl 2004, 103–107; see also ismi.mpiwg-berlin.mpg.de/witness/390019 – last accessed 2023-05-03.



(a) (b)

FIGURE 3. (a) shows a plate for determining the rising and setting times of the Moon, extracted from MS Berlin, Staatsbibliothek, Landberg 56, f. 93a (courtesy: Staatsbibliothek zu Berlin – Preußischer Kulturbesitz, Orientabteilung (digital.staatsbibliothek-berlin.de/werkansicht?PPN=PPN646157027&PHYSID=PHYS_0193&DMDID=DMDLOG_0001). (b) provides a simplified reconstruction of (a). The two outermost rims are not graduated in (b) since they simply represent the common division of each quadrant into 90° (including 5° intervals). For another reconstruction of figure 3 (a), see Charette and Schmidl 2004, 127 (Arabic) and 153 (English).

the numbers on the right, or northern, side by means of an alidade that is said to be attached in the middle of the plate.[45] They represent the rising and setting times of the Moon (see Fig. 3 and also Table 3). The text claims to take its numerical data from a table (*jadwal*) which is not preserved in the Berlin manuscript. To determine the time of moonset or moonrise, the user is required to follow two steps:

(1) Place the pointer of the alidade on the number that corresponds to the elapsed day of the lunar month on the left, or southern, half of the diagram.
(2) Read the number indicated by the other pointer of the alidade on the right, or northern, half of the diagram. This gives in the upper right, or north-western,

45. The reconstruction in Fig. 3 (b) features an alidade as mentioned in the accompanying text, although there is no indication of such a paper tool being installed on the extant diagram in MS Berlin. However, it is possible to use the diagram simply by temporarily placing a ruler or a sheet of paper on it, if not making a physical model.

quadrant the time of moonset for the first half of the month, in the lower right, or north-eastern, quadrant the time of moonrise for the second half.

The diagram in the Berlin manuscript is drawn carelessly and is unclear in some parts. The day numbers are consequently written in *abjad* notation, while those for the hours and minutes switch to the Hindu-Arabic numerals in the second part of the scale in the lower right quadrant. The scribe did not realise the distinct division of the inner rim, so it has more boxes than needed. To solve this problem, he either repeated the values or took advantage of the *abjad* letters' stretched style in writing.

Table 3: The values provided in al-al-Khwārazmī's text
(in the Berlin manuscript)

Day of the month	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
hour(s)	0	1	2	3	4	5	6	6	7	8	9	10	11	12
multiplied by $\frac{1}{7}$ = minutes	6	5	4	3	2	1	0	6	5	4	3	2	1	0

Despite having some errors, the values are fortunately recognisable. They follow the same rule as the reconstruction of al-Bakhāniqī's text (see Table 2), except they go one step further and display the result of the divisions by seven. Therefore, each value is presented by two numbers (see Table 3), the upper one specifying the quotient, that is the number of hours, and the lower one providing the remainder, which must be multiplied by $\frac{1}{7}$ to obtain the minutes.[46] Again, it gives moonset if we are in the first half of the month, and moonrise, if we are in the second half. For example, the third day of the month (ﺟـ) corresponds to the numbers «2» (ب) and «4» (د) on the right side of the plate (see Fig. 3 (a)); therefore, the Moon sets at $2\frac{4}{7}$ hours after sunset. Likewise, the Moon rises on the 17th night of the month at the same time as it sets on the third night, i.e., at $2\frac{4}{7}$ hours after sunset (see

46. Charette and Schmidl 2004, 176 suggest an alternative approximation which is based on considering the longitudinal rotation of the Moon being roughly as 50 minutes every day. Accordingly, the last row of Table 2 is interpreted by them as the sixths of an hour that need to be multiplied by 10 to obtain the minutes.

Table 3). Moreover, the sum of the two dashed arcs (see Fig. 3 (b)) measured according to the outermost rims gives the approximate longitudinal position of the Moon at sunset with respect to the horizon. This middle rim that allows to accurately measure this value, is called «the altitude circle» (*dāʾirat al-irtifāʿ*) by the author.

The *Tabṣira*'s table for the incomplete month, i.e., a lunar month with 29 days, is based on the same procedure. It gives, however, the final results of the required computation instead of mentioning it as two numbers (see Table 1 (a) and 1 (b) and the Appendix).

The symmetry between the two halves of the lunar month is a key point in the function of all the methods surveyed here, although they differ in their presentation. It allows condensed recipe-like descriptions alongside detailed schemes and tables. In comparison, the plate attributed to al-Khwārazmī is a materialised and hands-on method of applying this approximate method in which the two halves of the plate work as two columns that are connected through the symmetrical motion of an alidade hinged at the centre of the plate.

2.6 Rising and Setting Times of the Moon in Zījes

In the *zīj* literature, the times of moonrise and moonset are primarily presented as a by-product of the prevailing methods for rising and setting times of the celestial bodies. They owe their popularity to the centrality of finding the **ascendant** (*ṭāliʿ*) and the cusps of the houses for erecting a horoscopic chart and its interpretations as well as their application in telling time using the stars.[47]

The ascendant for a certain time and place is the point of intersection between the ecliptic and the eastern horizon (see Fig. 4). Accordingly, point M represents the ascendant at a certain time on a geographical location with latitude ϕ = arc PN, when looking at the rotation of the celestial sphere from the eastern side (point E is the East point). In the same manner, the **rising time** of a celestial body (L) is when it reaches the point L´, namely when it is about to rise above the horizon, following the daily revolution from East to West along the celestial equator.

However, the **degree of rising** (*darajat al-ṭulūʿ*) of a star or another celestial body is measured with respect to the intersection of the ecliptic with the horizon

47. See also «*Ṭāliʿ*» in *EI₂* by David A. King.

plane at the rising time (M) and the vernal equinox (V). Accordingly, arc VM represents the degree of rising for point M. The reference for measuring time intervals, however, is the corresponding length of the arc on the celestial equator. Thus, the arc of the celestial equator between the vernal equinox (V) and the East point (E) which rises simultaneously with arc VM on the ecliptic, i.e., arc VE, is called the **oblique ascension** (mostly known as *maṭāliʿ al-balad*) and determines how much later the star rises above the horizon than the vernal equinox.[48]

If the desired city is located on the equator (i.e., when $\phi = 0$), VE coincides with VO which is called the **right ascension** (commonly called *maṭāliʿ al-falak al-mustaqīm*).[49] The difference between oblique and right ascensions, i.e., arc EQ in Fig. 4, was called **equation of daylight** (*taʿdīl al-nahār*)[50].

Likewise, these arcs are defined at the setting of a star, although they are not as central as rising functions in the pre-modern sources. This set of relations, usually added with a number of auxiliary arcs, belong to the fundamental concepts in pre- and early modern Islamicate mathematical astronomy.[51]

Any celestial body, including the Moon, can be considered at point L´ and as a result, its rising and setting times will be obtained with the help of the spherical relations explained above. The rising time of the point M on the ecliptic can be determined through the following relation, as one of the two methods to calculate rising times in Ptolemy's *Almagest* (II.7) based on the renowned theorem of Menelaus:

$$\frac{\cos MQ}{\sin MQ} = \frac{\sin \phi}{\cos \phi} \cdot \frac{\sin ER}{\sin EQ}$$

Since $ER = 1$ the formula can be simplified as follows:

$$\sin EQ = \tan \phi \cdot \tan ER$$

48. See also «*Maṭāliʿ*» in *EI₂* by David A. King.

49. See also n. 49.

50. For an example of the explanation of these spherical functions in a pre-modern Arabic source, see Bagheri

2006, 145–174.

51. For a study on mathematical relations of rising times and respective functions in a pre-modern Arabic text, see Berggren and Van Brummelen 2001, 31–46.

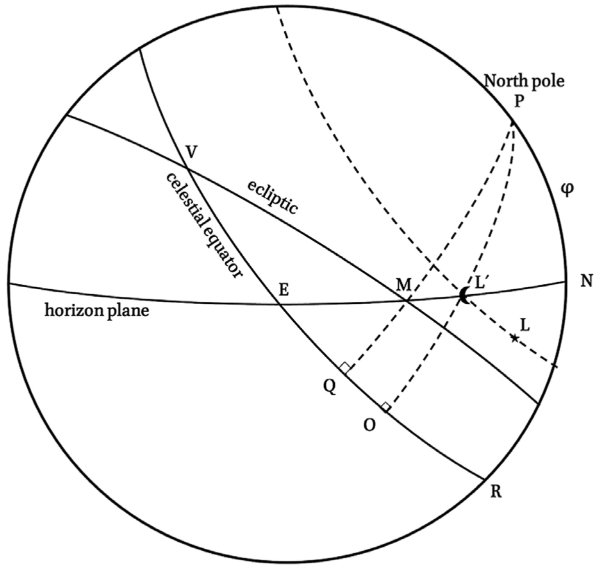


FIGURE 4. The Moon is rising above the horizon at point L´. P represents the North pole, E the east point, ϕ = arc PN the geographical latitude, and V the vernal equinox. Accordingly, arc VE on the ecliptic is the oblique ascension.

More relations were developed in the Islamicate *zīj*es and auxiliary arcs were tabulated and employed.[52] There are, however, only a few advanced texts known that mention the application of this method for the Moon. A worthy example occurs in the Berlin version of the *Zīj* attributed to Ḥabash al-Ḥāsib (d. after 255/869),[53] where the rising and setting times of the Moon are treated as questions of spherical astronomy, using the concept of the **degree of transit** (*darajat al-mamarr*), namely the point of the ecliptic that culminates (i.e., transits the meridian) at the same time as a given point on the celestial sphere.[54] The attribution of this text to Ḥabash is, however, uncertain. Since it is only preserved in one of

52. See n. 51. See also al-Bīrūnī's methods using *ortive* amplitude (*si'at al-mashriq*) in al-Bīrūnī, *Maqālīd 'ilm al-Hay'a*, 200–207. For general descriptions of mathematical relations regarding ascendant and ascensions, see Kennedy 1989, 18–19.

53. For manuscript Berlin, Staatsbibliothek Preußischer Kulturbesitz, Wetzstein I, 90, see Ahlwardt 1893, 200–203, no. 5750 and ismi.mpiwg-berlin.mpg.de/witness/191976 – last accessed 2023-05-04.

54. For the meaning and astrological usage of transits, see Kennedy 1958, 246–247.

the two existing versions of his *Zīj*, which is considered to be less reliable.[55] The heading of the text reads as *Maʿrifa ṭulūʿ al-qamar wa-maghībihi* («Knowledge of the Moon's rising and its setting»). Nevertheless, the aim of the chapter is far from providing a time-keeping table for regular usage, considering that no table or list of numbers is provided in the Berlin manuscript along with the mathematical description. Rather, it helps the professional audience to learn the procedure and to predict the position of the Moon on a given day.

The rising of the Moon also appears in the *Zīj al-Ṣābiʾ* by al-Battānī (d. 317/929), who only briefly addresses this question in the discussion of the parallax of the Moon.[56] The Moon at rising and setting times was also important in calculations related to eclipses.[57]

Different to the other methods introduced so far, the problem of the rising and setting times of the Moon is solved in the *zīj*-literature by means of arcs defined on the celestial sphere and their relation, a rather complex calculation that asks for a greater expertise to apply them than the methods with recipe-like descriptions, schemes, and tables in chapter xxiii of al-Ashraf ʿUmar's *Tabṣira*, and the books on *anwāʾ*, *filāḥa*, and *ʿilm al-mīqāt*. Furthermore, none of these examples found in the *zīj*es deal directly with timekeeping affairs.

3. Moonrise and Moonset in Everyday Practices

The examples presented address moonrise and moonset in works belonging to different genres and disciplines and obtained through diverse methods. This variety might indicate an interest in this knowledge of various groups of people, in particular practitioners. Knowing the anticipated level of lunar illumination for a given night can prove very helpful in various contexts, e.g., in military campaigns; given that weather forecast texts suggest that their meteorological knowledge was estimated advantageous for them,[58] a similar utility may be attributed to the

55. According to a study by Marie-Thérèse Debarnot (1987, 36–37), the moonrise method only appears in the Berlin version of Ḥabash al-Ḥāsib's *Zīj*, fol. 152a–153b, and is completely absent in the other version, i.e., Istanbul, Süleymaniye Library, Yeni Cami 784, which she considers the more authentic one.

56. Nallino 1899–1907, vol. 3: 124–125.

57. E.g., al-Bīrūnī, *al-Qānūn al-Masʿūdī*, vol. 2: 938–939.

58. Burnett 2021, 689.

prediction of moonrise and moonset. Methods for finding the Moon's position with respect to the horizon also emerge in a number of *ʿilm al-mīqāt* texts, that might be explained by the use of the Moon to determine the time of the evening prayer (*ṣalāt al-ʿishāʾ*) in a few *ḥadīth*s.[59] Further, moonlight is regarded benefic in agriculture, e.g., when Shams al-Dīn al-Samarqandī (d. *ca*. 722/1322) attempts to philosophically explain how moonlight impacts the growth of plants.[60] Abū Maʿshar (d. 272/886) alludes to the correlation between the Moon's presence or absence above the land and the production of milk and eggs:

> As for day and night, when the Moon is above the earth in the eastern quadrant or in the azimuth of a certain place, it makes the milk of the udders of their sheep abundant and increases both it and the brains of their animals. If eggs are produced in the bellies of birds at that time, their whiteness will be richer than that of eggs produced in their bellies at another time of the day and night.[61]

4. Conclusion

This paper undertakes a mathematical and historical examination of al-Ashraf ʿUmar's method, comparing it to similar approximate instructions and advanced accounts in the Islamicate sources. The analysis of these methods reveals that while Islamicate scientific texts provided precise means of determining night-time based on the Moon's motion, approximate methods earned notable popularity in various genres and disciplines. This observation highlights that different time measurement approaches might be tailored to specific needs and perspectives of practitioners. While the mathematical texts offer general techniques applicable to all celestial bodies, other texts place particular stress on inquiring about the moonrise and moonset times.

Furthermore, the paper emphasises that despite sharing a common observational foundation, the approximate methods reviewed here adopt distinct formats and languages when situated within the literary context of a particular discipline and its intended audience. The study also underscores the algorithmic nature and sim-

59. For two examples of these *ḥadīth*s, see Schmidl 2007, 55.
60. Al-Samarqandī, *ʿIlm al-āfāq wa-l-anfus*, 240.
61. For the Arabic text and English translation, see Yamamoto and Burnett 2019, 338–339.

plicity of these methods, rendering them easily applicable in everyday life. This feature, previously observed in al-Ashraf ʿUmar's other chapters, sheds further light on the purpose and functionality of the *Tabṣira*.

Additionally, the paper explores the varying practical applications of these methods. Practices such as agriculture, prayer times, and nocturnal time regulation are examined, wherein the horizontal position of the Moon was believed to hold significance. Although not explicitly mentioned in any text, knowledge of moonlight duration could potentially prove valuable in other night-time activities, such as military campaigns, social gatherings, or night travel.

Appendix

Arabic Text and English Translation of al-Ashraf ʿUmar's Tabṣira*, Chapter xxiii*

(a) Editorial Conventions

This section presents the Arabic text and English translation of chapter xxiii in al-al-Ashraf ʿUmar's *Kitāb al-Tabṣira* (fol. 48b,1–50a,4 in manuscript Oxford, Bodleian Library, Huntington 233, henceforth: H, omitted in manuscript Paris, Bibliothèque nationale de France, arabe 2601.2, henceforth: P). In the Arabic text *hamza*, *madda*, *shadda*, and diacritical points have been silently added. Spelling mistakes of numerals are not corrected. The punctuation marks follow the manuscript by presenting paragraph marks either by dots (in case of a blank space), by [ـى] ـهـ [انتـ] (in case of ـهـ), or three dots forming a triangle. Paragraphs are numbered in square brackets [ ], folios provided in angular brackets < >. In the Arabic text, words are put in square brackets [ ] whose reading can be deduced. In the English translation, parentheses ( ) have been inserted to assist the flow of the text while square brackets [ ] denote paragraph numbers as well as additional explanations, < > emendations by the authors. Emphasis by rubrication in the Arabic text follows the manuscript and is rendered by bold, red script in the English translation (online edition) and bold (English translation, printed edition).

(b) Arabic Text

< H,48b > [1] **البـــــــاب الثالث والعشرون في معرفة طلوع القمر ومغيبه في ليالي الشهر العربي التامّ وليالي الشهر العربي الناقص**

[2] إذا أردت أن تعرف ما مضى [من الليل] من الشهر العربي التامّ فاعرف ما مضى من لياليه واضربه في أربعة فما بلغ الضرب فأسقطه على خمسة خمسة لكلّ ساعة مهما بقي من العدد لم يتمّ خمسة فهو كسور من أخماس ساعة .

[3] **مثاله** إن قد دخل من الشهر العربي التامّ أربع ليالي فاضرب أربعة في أربعة يكون ستّة عشر فأسقط خمسة عشر لثلاث [؟] ساعات يبقى من العدد واحد فتكون خُمس ساعة فتلك الليلة يغيب القمر على ثلث ساعات وخمس ساعة وكذلك إذا أردت أن تعلم طلوعه من النصف الأخير فاضرب من الليلة السادسة عشر واحد في أربعة فذلك أربعة أخماس ساعة فالقمر يطلع تلك الليلة على أربعة أخماس ساعة . وإن دخل [من النصف الأخير] من الشهر العربي أربع ليالي وهي ليلة التاسع عشر فاضرب أربعة في أربعة كما تقدّم في أوّله فيكون طلوع القمر تلك الليلة على ثلث ساعات وخمس والله أعلم .

[4] **وأمّا الشهر الناقص** فإنّك تضرب ما دخل من ليالي الشهر العربي في ستّة أصلاً أبداً مهما بلغ من الضرب فأسقطه لكلّ ساعة سبعة فما لم يفّ سبعة . فيسمى أسباعاً . **مثال ذلك** إذا مضى من الشهر أربع ليالي فاضرب أربعة في ستّة يكون أربعة وعشرين فيكون مغيب القمر في تلك الليلة على ثلث ساعات وثلثة أسباع ساعة . وكذلك طلوعه يُحسَب من السادسة عشرة لأنّه في الخامسة عشرة يطلع عند غروب الشمس فيكون طلوعه ليلة التاسع عشر على ثلث ساعات وثلثة أسباع ساعة على ما يأتي ذكره إن شاء الله تعالى .

[٥] **معرفة طلوع القمر ومغيبه في ليالي الشهور العربيّة التّامّة**

الليلة الأولى	يغيب القمر على أربعة أخماس ساعة
الليلة الثانية	يغيب القمر على ساعة وثلثة أخماس ساعة
الليلة الثالثة	يغيب القمر على ساعتين وخمسي ساعة
الليلة الرابعة	يغيب القمر على ثلث ساعات وخمس ساعة
الليلة الخامسة	يغيب القمر على أربع ساعات[62] سواء
الليلة السادسة	يغيب القمر على أربع ساعات وأربعة أخماس < H,49a >
الليلة السابعة	يغيب القمر على خمس ساعات وثلثة أخماس
الليلة الثامنة	يغيب القمر على ستّ ساعات وخمسين

62. H writes ساتٍ.

الليلة التاسعة	يغيب القمر على سبع ساعات وخمس
الليلة العاشرة	يغيب القمر على ثماني ساعات سواء
الليلة الحادية عشرة	يغيب القمر على ثماني ساعات وأربعة أخماس
الليلة الثانية عشرة	يغيب القمر على تسع ساعات وثلثة أخماس
الليلة الثالثة عشرة	يغيب القمر على عشر ساعات وخمسين
الليلة الرابعة عشرة	يغيب القمر على إحدى عشرة ساعة وخمس
الليلة الخامسة عشرة	يغيب القمر على اثنتي عشرة ساعة سواء
الليلة السادسة عشرة	يطلع القمر على أربعة أخماس ساعة
الليلة السابعة عشرة	يطلع القمر على ساعة وثلثة أخماس ساعة
الليلة الثامنة عشرة	يطلع القمر على ساعتين وخمسين
الليلة التاسعة عشرة	يطلع القمر على ثلث ساعات وخمس
الليلة العشرون	يطلع القمر على أربع ساعات سواء
الحادية والعشرون	يطلع القمر على أربع ساعات وأربعة أخماس
الثانية والعشرون	يطلع القمر على خمس ساعات وثلثة أخماس
الثالثة والعشرون	يطلع القمر على ستّ ساعات وخمسين
الرابعة والعشرون	يطلع القمر على سبع ساعات وخمس ساعة
الخامسة والعشرون	يطلع القمر على ثماني ساعات سواء
السادسة والعشرون	يطلع القمر على ثماني ساعات وأربعة أخماس
السابعة والعشرون	يطلع القمر على تسع ساعات وثلثة أخماس
الثامنة والعشرون	يطلع القمر على عشر ساعات وخمسي ساعة
التاسعة والعشرون	يطلع القمر على إحدى عشرة ساعة وخمس ساعة
الليلة[63] الثلثون	يطلع القمر على اثنتي عشرة ساعة سواء

[6] معرفة طلوع القمر ومغيبه في ليالي الشهور العربية الناقصة < H,49b >

الليلة الأولى	يغيب القمر على ستّة أسباع ساعة
الليلة الثانية	يغيب القمر على ساعة وخمسة أسباع
الليلة الثالثة	يغيب القمر على ساعتين وأربعة أسباع
الليلة الرابعة	يغيب القمر على ثلث ساعات وثلثة أسباع
الليلة الخامسة	يغيب القمر على أربع ساعات وسبعين
الليلة السادسة	يغيب القمر على خمس ساعات وسبع

63. H writes الساعة .

الليلة السابعة	يغيب القمر على ستّ ساعات سواء
الليلة الثامنة	يغيب القمر على ستّ ساعات وستّة أسباع
الليلة التاسعة	يغيب القمر على سبع ساعات وخمسة أسباع
الليلة العاشرة	يغيب القمر على ثماني ساعات وأربعة أسباع
الليلة الحادي عشرة	يغيب القمر على تسع ساعات وثلثة أسباع
الليلة الثانية عشرة	يغيب القمر على عشر ساعات وسبعين
الليلة الثالثة عشرة	يغيب القمر على إحدى عشرة ساعة وسبع
الليلة الرابعة عشرة	يغيب القمر على اثنتي عشرة ساعة سواء
الليلة الخامسة عشرة	يغيب القمر[64] عند طلوع الشمس سواء
الليلة السادسة عشرة	يطلع القمر على ستّة أسباع ساعة
الليلة السابعة عشرة	يطلع القمر على ساعة وخمسة أسباع
الليلة الثامنة عشرة	يطلع القمر على ساعتين وأربعة أسباع
الليلة التاسعة عشرة	يطلع القمر على ثلث ساعات وثلثة أسباع
الليلة العشرون	يطلع القمر على أربع ساعات وسبعين
الحادية والعشرون	يطلع القمر على خمس ساعات وسبع
الثانية والعشرون	يطلع القمر على ستّ ساعات سواء
الثالثة والعشرون	يطلع القمر على ستّ ساعات وستّة أسباع
الرابعة والعشرون	يطلع القمر على سبع ساعات وخمسة أسباع
الخامسة والعشرون	يطلع القمر على ثماني ساعات وأربعة أسباع < H,50a >
السادسة والعشرون	يطلع[65] القمر على تسع ساعات وثلثة أسباع
السابعة والعشرون	يطلع القمر على عشر ساعات وسبعين
الثامنة والعشرون	يطلع القمر على إحدى عشرة ساعة وسبع
التاسعة والعشرون	يطلع القمر على اثنتي عشرة ساعة سواء

64. H adds على and crosses out.
65. H writes يطيب (?).

(c) English Translation

<H,48b> [1] The twenty-third chapter on the determination of the rising of the Moon and its setting in the nights of a complete Arabic month and in the nights of an incomplete Arabic month.

[2] If you want to determine what has passed (from the nights) of a complete Arabic month, then determine what has passed from its nights and multiply it by four, so what the multiplication yields, separate five by five [i.e., divide by five] for each hour. Any number less than five that remains will be a fraction of fifths [*akhmās*] of an hour.

[3] **An example of it**: If the fourth night of a complete Arabic month is entered, then multiply four by four to be sixteen, and subtract fifteen – for three hours – from it, leaving one, which derives one-fifth of an hour. Thus, the Moon sets that night at three hours and a fifth of an hour. Likewise, if you want to know its rising in the latter half (of the month), then multiply one by four for the sixteenth night, which results in four fifths of an hour. Thus, the Moon rises that night at four fifths of an hour. If it is the fourth night of (the latter half) of the Arabic month, that is the nineteenth night, then multiply four by four, as was said about the first half. Thus, the Moon rises that night at three hours and a fifth. And God knows best.

[4] **As for the incomplete month**, you multiply what is entered from the nights of the Arabic month by six at all, then (repeatedly) subtract seven from whatever results from the multiplication to obtain hours. So, what does not compound seven is called sevenths [*asbāʿ*]. **An example of that**: If four nights of the month have passed, then multiply four by six, which become twenty-four. Thus, the Moon sets that night at three hours and three seventh. Likewise, its rising is calculated from the sixteenth in the same way, because in the fifteenth it rises at sunset. Thus, its rising on the nineteenth night will be at three hours and three sevenths of an hour, according to what comes to be mentioned, and God the Exalted willing.

[5] **Determination of the rising of the Moon and its setting in the nights of the complete Arabic months**

First night	The Moon sets at four fifths of an hour
Second night	The Moon sets at one hour and three fifths of an hour
Third night	The Moon sets at two hours and two fifths of an hour
Fourth night	The Moon sets at three hours and a fifth of an hour
Fifth night	The Moon sets right at four hours
Sixth night	The Moon sets at four hours and four fifths <H,49a>

Seventh night	The Moon sets at five hours and three fifths
Eighth night	The Moon sets at six hours and two fifths
Ninth night	The Moon sets at seven hours and a fifth
Tenth night	The Moon sets right at eight hours
Eleventh night	The Moon sets at eight hours and four fifths
Twelfth night	The Moon sets at nine hours and three fifths
Thirteenth night	The Moon sets at ten hours and two fifths
Fourteenth night	The Moon sets at eleven hours and a fifth
Fifteenth night	The Moon sets right at twelve hours
Sixteenth night	The Moon rises at four fifths of an hour
Seventeenth night	The Moon rises at one hour and three fifths of an hour
Eighteenth night	The Moon rises at two hours and two fifths
Nineteenth night	The Moon rises at three hours and a fifth
Twentieth night	The Moon rises right at four hours
Twenty-first night	The Moon rises at four hours and four fifths
Twenty-second night	The Moon rises at five hours and three fifths
Twenty-third night	The Moon rises at six hours and two fifths
Twenty-fourth night	The Moon rises at seven hours and a fifth of an hour
Twenty-fifth night	The Moon rises right at eight hours
Twenty-sixth night	The Moon rises at eight hours and four fifths
Twenty-seventh night	The Moon rises at nine hours and three fifths
Twenty-eighth night	The Moon rises at ten hours and two fifths of an hour
Twenty-ninth night	The Moon rises at eleven hours and a fifth of an hour
Thirtieth night	The Moon rises right at twelve hours

[6] **Determination of the rising of the Moon and its setting in the nights of the incomplete Arabic months <H,49b>**

First night	The Moon sets at six sevenths of an hour
Second night	The Moon sets at one hour and five sevenths
Third night	The Moon sets at two hours and four sevenths
Fourth night	The Moon sets at three hours and three sevenths
Fifth night	The Moon sets at four hours and two sevenths
Sixth night	The Moon sets at five hours and a seventh
Seventh night	The Moon sets right at six hours
Eighth night	The Moon sets at six hours and six sevenths
Ninth night	The Moon sets at seven hours and five sevenths
Tenth night	The Moon sets at eight hours and four sevenths
Eleventh night	The Moon sets at nine hours and three sevenths

Twelfth night	The Moon sets at ten hours and two sevenths
Thirteenth night	The Moon sets at eleven hours and a seventh
Fourteenth night	The Moon sets right at twelve hours
Fifteenth night	The Moon sets right at the sunrise
Sixteenth night	The Moon rises at six sevenths of an hour
Seventeenth night	The Moon rises at one hour and five sevenths
Eighteenth night	The Moon rises at two hours and four sevenths
Nineteenth night	The Moon rises at three hours and three sevenths
Twentieth night	The Moon rises at four hours and two sevenths
Twenty-first night	The Moon rises at five hours and a seventh
Twenty-second night	The Moon rises right at six hours
Twenty-third night	The Moon rises at six hours and six sevenths
Twenty-fourth night	The Moon rises at seven hours and fifth sevenths
Twenty-fifth night	The Moon rises at eight hours and four sevenths <H,50a>
Twenty-sixth night	The Moon rises at nine hours and three sevenths
Twenty-seventh night	The Moon rises at ten hours and two sevenths
Twenty-eighth night	The Moon rises at eleven hours and a seventh
Twenty-ninth night	The Moon rises right at twelve hours

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