Spherical astrolabes in circulation

From Baghdad to Toledo and to Tunis & Istanbul

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Before citing please make sure you are using the most recent version. Previous versions contained incorrect interpretations of ZAIM based on partial evidence.

Illustrations

Detailed images of each of the three spherical astrolabes are appended in separate files. For permission to use these I am grateful to Ernesto Canobbio (TUNIS), Silke Ackermann (MUSA), and an anonymous private collector (ZAIM). Different images of MUSA are available on the Oxford MHS website.

Note about software used:

Some reviewers of my earlier publications – books for which I prepared a camera-ready copy – have found my comments on production difficulties of considerable interest, not least for the sake of posterity. Here are some new ones.

The Apple software PAGES 7.1 for an MacOS Sierra 10.12.6 used to prepare this monograph in 2018 is not without its problems.

PAGES lacks several of the other features that MS Word had 20 years ago, such as the ability to (1) sort lists simply, either alphabetically or numerically, without first formatting them in tables, and (2) create invisible text. Likewise, PAGES does not permit viewing different parts of a document at the same time. This made comparing the two sets of stars lists far more difficult than it needed to be.

PAGES does not permit automatic cross-references! The presence of cross-references here is indicated with #. For the present, footnote-numbers referenced may be 'off' by a few digits.

PAGES causes illustrations to wander around the text and jump from one page to another when modifications are made to the text. For each new version they had to be moved back to their correct places.

Worst of all for camera-ready copy, PAGES creates large unwanted spaces in the text, which apparently cannot be removed by a normal user (see, for example, p. 9 below).

Somehow life was easier in the old days and printouts were better.

Summary

The spherical astrolabe is one of several astronomical instruments invented by the astronomers of Baghdad in the 9th century, at a time when that city was the leading and most vibrant scientific centre in the world. Two such spherical astrolabes have been known since the early 1960s, both with Arabic inscriptions. The one that is complete is signed simply "made by Mūsà in the year 885", the Hijra year corresponding to 1480/81, and it is preserved in the Museum of the History of Science at Oxford. The other, alas lacking its star-map (rete), is unsigned but made in Tunis, and it belongs to a private collection in Italy. The Tunis instrument is perhaps earlier than the Oxford one. Both instruments have been published with detailed descriptions but there is more that can be said,

The purpose of this study is to take a fresh look at both instruments and also to investigate the context of the astronomy and the astronomical instrumentation which was practiced in the milieus from which they hail.

In preparing a new description of the Oxford spherical astrolabe it was essential to find out more about "Mūsà", whose name has been known for over 50 years, but whose identity or location have not been established previously. Here we are aided by the fact that the latitude underlying the seasonal-hour markings on the Oxford sphere is around 41°, which, within the context of medieval Islamic instrumentation, can only serve Istanbul.

It is suggested here that the maker of the Oxford instrument is none other than Mūsà Jālīnūs, a remarkable Jewish medic and astronomer with access to the court of Sultan Bāyazīt II (*reg*. 1481-1512) in the recently established Ottoman capital of Istanbul. He also had a connection to the military. Mūsà's principal written works have only been investigated during the past 10 years. He is now known as the author of various sophisticated treatises on astronomy and medicine, as well as philosophy. He was a gifted linguist, writing in Arabic, Hebrew and Turkish, and translating from Latin into Arabic and from Arabic into Hebrew. His interest in practical devices was not limited to astronomical instruments for it extended to mechanical devices and even robotics. He visited Venice and Padua between 1497 and 1502 and must be considered as a possible vehicle in the transmission of certain innovative ideas in Islamic theoretical astronomy to Renaissance Europe.

The Oxford spherical astrolabe is elegantly executed with obvious technical skill. It features some problems of Arabic orthography such as

are not attested on any of the hundreds of Islamic planispheric astrolabes that are known to us. However, some of the 19 star-pointers on it are in the wrong positions, and the star-names are not easy to interpret because they are abbreviated and somewhat cryptic. For reasons of symmetry the stars chosen are rather dim (all magnitude 2 to 4!), the one exception being the bright star Arcturus, which is actually in the wrong position. Such features would render the complicated instrument non-functional.

We also discuss a 'new' spherical astrolabe that has recently come to light. It strongly resembles the instrument of Mūsà, but it is signed by the enigmatic "al-Zaʿīm", which is more of a title than a name. One might think that this new instrument, which has many problems in its markings and its inscriptions, let alone the star-pointers, could be earlier than that of Mūsà and that it might to some extent explain the minor defects of the one signed by Mūsà. But one would be mistaken, for the 'new' instrument of al-Zaʿīm is a recent production. It is signed with a mysterious name with strong medieval connotations but it is not dated, so we should not necessarily call it a fake. It does not claim to be anything more than what it is, namely, a spherical astrolabe by someone who calls himself or is called by others "al-Zaʿīm". On the other hand, the effort required to make it must have been so substantial that those responsible for it must have anticipated a handsome reward in a sale or an auction. Let us say that it is a decorative spherical astrolabe of uncertain, but very recent, provenance.

In preparing this study the author has found it not without interest to document some of the astronomical background of 13th-,14th- and 15th-century Tunis and late-15th-century Istanbul. Most people are unaware that there ever was any serious astronomy in Tunis in particular or the Maghrib in general, but indeed there was, and it has been documented mainly by Julio Samsó and his colleagues in Barcelona with some contributions by the present writer. And it seems to be generally thought that astronomy under the Ottomans started with the famous but short-lived observatory at Istanbul under Taqi 'l-Dīn in the late 16th century. The present study offers some insights into what was going on in Istanbul a century earlier. In particular, it draws attention to the sophisticated tables for astronomical timekeeping and regulating the astronomically-defined times of prayer used by Ottoman astronomers, which are never mentioned in generalizations about Ottoman astronomy or Ottoman timekeeping.

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1 Introductory remarks

> "Each medieval instrument can tell us something that contributes to the overall picture. The time is ripe for the further study of related groups of instruments, with the aim of learning about the workshops in which they were constructed, why they were made, and how they were used. ... Medieval instruments constitute a veritable goldmine of historical sources still to be exploited." DAK, "Making instruments talk – Some medieval astronomical instruments and their secrets" (1995), available at www.davidaking.academia.edu, currently (2018) at www.academia.edu/34695170/.

Muslim astronomers were the leaders in their field from the 8th to the 15th century. Yet only a small fraction of the Islamic literary and material scientific heritage has come down to us, and many people think that the history of Islamic science has already been written. The sources that survive and confront the diligent researcher include over 10,000 Arabic, Persian and Turkish manuscripts relating to astronomy and mathematics, and close to 1,000 astronomical instruments. These represent but a small portion of the entire corpus that was available in major centres over the centuries. And only very few of the available sources have ever been researched and inserted into the general picture, enough, I would claim, to demonstrate not least that further research is worthwhile.[1]

The texts that confront us are of six main kinds:

(1) treatises on folk astronomy, that is, what can be seen of the heavenly motions without instruments, geometrical models or calculation;

(2) treatises on theoretical astronomy and geometrical models to represent the motions of the sun, moon, and planets;

(3) astronomical handbooks called *zīj*es with extensive tables and explanatory text, of which over 200 are known;

(4) ephemerides called *taqwīm*s prepared annually showing the positions of the sun, moon and planets for each day of a given year;

(4) tables for astronomical timekeeping and regulating the astronomically-defined times of Muslim prayer, of which dozens of examples are known, and tables and/or methods for determining the sacred direction (*qibla*) toward the Kaaba in Mecca;

(5) treatises on instruments, from large-scale observational ones to spheres, astrolabes, quadrants, sundials, ... ; and

(6) treatises and tables for astrology.

Considerable progress has been made over the past century toward the further documentation of the history of Islamic science by scholars of divers nationalities, with fortunately not all of them interested only in transmission <u>to</u> the new Islamic world (mainly from the Hellenistic world but also from Iran and India), or transmission <u>from</u> the Islamic world to

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1 Compare the following overviews: Nallino, “[Islamic astronomy]” (1921); King, “Islamic astronomy” (1996); and Morrison, “Islamic astronomy and astrology” (2010).

For an overview of *zīj*es and other kinds of tables see King & Samsó & Goldstein, “Astronomical handbooks and tables from the Islamic world (750-1900)”. This does not replace Kennedy, “Survey of Islamic astronomical tables” (1956, and is intended only as a temporary overview of the subject prior to the forthcoming monumental *zīj* survey of Benno van Dalen. See already his 2014 publication *Islamic Astronomical Tables*.

For an overview of medieval instruments – Byzantine, Islamic, Latin – see King, “Astronomical instruments between East and West” (1994), and on Islamic instruments other than globes see King, *In Synchrony with the Heavens*, I “Astronomical instrumentation in the medieval Islamic world” and XIIIa “On the favourite astronomical instrument of the Middle Ages”: 1-110 and 337-402.

Europe (mainly *via* Spain), but rather in what Muslim scholars did within their own culture between al-Andalus and India, and between Central Asia and the Yemen. The problem that specialists in the history of Islamic astronomy confront is that the modern Western world is under the impression that Islamic astronomy is somehow represented by the 5% of it that became known in medieval Europe, and the modern Islamic world is unfortunately barely aware even of that. More recently it has been discovered that some aspects of Islamic astronomy came to Renaissance Italy from Istanbul, with Jews as the principal intermediaries. What is true of ideas is also true of instruments.[2]

One problem confronting us is that the sources which offer the most challenge to future historians are housed in the rich libraries of Turkey and Iran, mainly catalogued only recently. Yet even in various Western libraries where the astronomical manuscripts are properly catalogued, briefly listed in out-dated catalogues, or not catalogued at all, important discoveries can still be made. Witness the materials in Arabic, Hebrew, and Turkish mentioned later in this paper, and no less the instruments that we shall discuss.

Out of the several hundred surviving Islamic astronomical instruments the majority are planispheric astrolabes (اسطرلاب مسطح , *asṭurlāb musaṭṭaḥ*) and just two – until recently – are spherical astrolabes (اسطرلاب كري or كروي , *asṭurlāb kurī* or *kurawī*). Yet we know that spherical astrolabes were made on and off from the 9th until maybe the 16th or 17th century. It should not surprise any historian of Islamic astronomy or indeed any historian of science that a ‘new’ Islamic spherical astrolabe should turn up ‘out-of-the-blue’ with a signature of a maker completely unknown to the specialist literature. But is that instrument genuine?

There is a tendency amongst some modern scholars to pronounce any historical instrument which they do not understand as a fake, or at least as dubious. “Must be a fake,” these words have rung through the halls of several museums and universities in recent decades in relation to the most historically-significant medieval instruments that have survived the

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2 See my March 2018 lecture at the Al-Furqan Foundation in London on instruments from the European Renaissance and earlier examples of Islamic instruments of the same kind at www.youtube.com/watch?v=KmsixNDb7oo (2018), starting at 50 minutes (following my lecture “Astronomy in the Service of Islam”).

vicissitudes of time.[3] It is a fact of instrumental life that once an instrument has been labelled suspicious or a fake by some ‘expert’ who actually has no idea, it will always be considered ‘doubtful’ or ‘suspect’ by the unsuspecting for perpetuity.

This author has argued elsewhere for closer investigation of particular instruments of exceptional interest within the context of the relevant regional school of astronomy and astronomical instrumentation. However, the documentation of the activities of most of these regional schools, Islamic and European, is a task for the future.

Spherical instruments in ancient and medieval astronomy

The ancient Greeks conceived of a celestial sphere, bearing various bright stars, sitting inside a frame of two rings, one representing the horizon and the other the meridian. The sphere could rotate about a celestial axis, a diameter of the meridian inclined above the horizon at the north point by an amount equal to the local latitude. The Muslims called this instrument ذات الـــكرســـي , *dhāt al-kursīy*, “(the sphere) with the horizon base”, the medieval Europeans *sphaera solida*, “the solid sphere”.[4]

That the Ancient Greeks had highly sophisticated spherical instruments marked with seasonal hours in different manifestations, far more sophisticated than standard celestial globes, is now well established, but these were not spherical astrolabes and they are now described as “globe

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3 Details are given in my 2018 study “The astrolabe”. The claims that the ‘Destombes astrolabe’ was in some way “dubious” have been successfully disproved by showing that all evidence points to an origin in 10th-century Catalonia. The outrageous suggestion that the ‘Regiomontanus astrolabe of 1462’ was in some way “dubious” or even “fake” could be dismissed by showing that it was one out of 11 surviving pieces from the same Viennese workshop. The “*latin de cuisine*” of its inscription is, in fact, one of the most brilliant acrostics of the Renaissance. The claims that a 17th-century Iranian world-map with a cartographic grid preserving direction and distance to Mecca at the centre ‘“must have been of European inspiration” were shown to be invalid with the discovery of two more such maps as well as Arabic texts from the 10th and 11th centuries presenting the mathematics underlying the grids. ... .

4 The basic work on Islamic globes is Savage-Smith, *Islamicate celestial globes.* See also the catalogue of a recent exhibition in the Louvre Abu Dhabi entitled *Globes: Visions of the World* (Hoffmann & Nawrocki, eds.) which missed the opportunity to feature the Oxford spherical astrolabe.

dials", an expression which can hardly convey any idea of their complexity. Fortunately they have now been analyzed in detail.[5]

Muslim astronomers from the 9th century onwards knew that the earth was spherical. They made observations to measure its circumference and they derived a more accurate value than the Ancient Greeks.[6] Being aware that the heavens appear to rotate about the sky of the observer, they too found it convenient to consider these on a celestial sphere.

A new device, the spherical astrolabe, to show the heavens, represented by selected stars on a rete with an ecliptic as circumference, rotating over a spherical globe marked with the coordinate system of the sky above the horizon of the observer was apparently invented in 9th-century Baghdad.[7] One variety could feature stars north of the ecliptic, the other those south of it. It has been argued by some modern scholars that the spherical astrolabe was derived from the planispheric astrolabe, which the Muslims inherited from the Greeks, but perhaps the only reason for this incorrect assertion is that the Muslims inherited the planispheric astrolabe in the 8th century and invented the spherical astrolabe in the 9th.[8]

The standard astrolabe is a two-dimensional representation of the three-dimensional celestial sphere.[9] The 'celestial part' – the rete شبكة , *shabaka* with star pointers and circle for the ecliptic, that is, the apparent path of the sun against the background of fixed stars – can be made to rotate over the

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5 Schaldach & Feustel, "The Globe Dial of Prosymna" (2013).

6 See King, "Earliest Muslim geodetic measurements", and the literature there cited.

7 The possibility of a Greek predecessor is discussed in Seeman & Mittelberger, "Das kugelförmige Astrolab ... " (1925)., pp. 3-5. This should be investigated further, since our knowledge of portable instruments from that milieu has increased considerably over the past few decades.

8 On the spherical astrolabe within the context of Islamic instrumentation see Vernet & Samsó, *El legado científico andalusí*, p. 220; and King, *In Synchrony with the Heavens*, I:5 "Astronomical instrumentation in the medieval Islamic world", "Non-standard astrolabes": pp. 68-69.

9 For a new look at astrolabes in medieval Islamic and European astronomy see King, "What is an astrolabe and what is an astrolabe not" (2018), with an extensive bibliography, intended as a supplement to the already substantial literature on the astrolabe.

'terrestrial part' – one of several plates صـفيحة ج. صـفائـح , *ṣafīḥa*, pl. *ṣafā'iḥ* showing the horizon and altitude circles up to the zenith for each of the seven climates of Antiquity, or for a series of latitudes. Such a series of plates serves to make the instrument 'universal', that is, serving numerous or all latitudes. The Muslims encountered the astrolabe around 750 in the city of Ḥarrān, near what is now the border between Syria and Turkey. A 10th-century report mentions that the first Muslim to have made an astrolabe was Ibrāhīm al-Fazārī, an astronomer and astrologer from an old Arab family in Kufa in Iraq, also known to have developed other kinds of instruments.[10] Later astronomers in Baghdad conceived all manner of minor modifications and useful additions to the instrument, although its basic function as a 'mirror' of the universe or, to use a modern expression, an analogue computer, remained unchanged for the next millennium.

It was apparently the brilliant Ḥabash al-Ḥāsib who in the 9th century first thought of making a spherical astrolabe, with a hemispherical rete bearing the star-pointers and ecliptic-ring that could rotate over a sphere bearing markings for a horizon and altitude circles. Again, this instrument could serve a specific latitude, with latitude dependent markings for the seasonal hours, or be adjustable to serve any latitude.

The spherical astrolabe is yet another "universal solution" proposed by a series of Muslim astronomers between the 9th and 15th centuries for problems of spherical astronomy – the study of the apparent daily motion of the celestial sphere about the observer.[11] It does not appear to have been widely used, and until recently just two examples were known to have survived, both Islamic.

We should stress that spherical astrolabes have on their retes only stars that are north of the ecliptic or stars that are south of it. These are called northern or southern, but in this study, we shall be dealing only with the northern variety. Then they may have a latitude scale for setting the instrument to any particular latitude. Thus the instrument is universal. However, the sphere may bear seasonal hour markings for a specific latitude, but these should not be used if the instrument is set for a different

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10 On al-Fazārī see the articles by Kim Plofker in *BEA* and Julio Samsó in *Encyclopedia of Islam Three*.

11 See King, "Universal solutions in Islamic astronomy" (1987), specially p. 704 on the spherical astrolabe, and "Universal solutions to problems of spherical astronomy from Mamluk Egypt and Syria" (1988).

latitude. In this study we shall not discuss the use of the spherical astrolabe, which as we shall see below are well documented by Seemann & Mittelberger (in German) and by Ornella Marra (in Italian), but roughly we can say that they are similar to the operations of the standard astrolabe.

The celebrated 13th-century Syrian historian Ibn Khallikān records an anecdote, now well-known, about the invention of the astrolabe.[12] Ptolemy was riding on the back of a donkey and carrying a celestial sphere; inevitably he dropped it, the animal trod on it and squashed it, and the result was the astrolabe. Ibn Khallikān went on to mention the linear astrolabe[13] developed by the 12th-century scholar Sharaf al-Dīn al-Ṭūsī[14] in Baghdad and improved shortly thereafter by his own contemporary Kamāl al-Dīn ibn Yūnus,[15] whom the historian had met in Baghdad. With this ingenious device, serving a specific latitude, one can solve all of the problems that one can solve with an astrolabe and a single plate for that latitude. Ibn Khallikān did not mention the spherical astrolabe, but he did

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12 King, "Origin of the astrolabe according to the medieval Arabic sources", pp. 54-55 and 71, and pp. 594-595 and 607, of the new version in *In Synchrony with the Heavens*.

13 The standard works are Carra de Vaux, "L'astrolabe linéaire ou bâton d'al-Tousi" (1895); Michel, "L'astrolabe linéaire d'al-Tusi" (1943); *idem*, *Traité de l'astrolabe* (1947), pp. 115-122. See also Charette, *Mathematical instrumentation in 14th-century Egypt and Syria*, pp. 62-63.

Every few years someone comes up out of the blue with their own description of the instrument and its *modus operandi*. See, for example, Goretti, "The linear astrolabe of al-Tusi" (2009).

Also in 2009 Sajjad Nikfahm-Khubravan completed a Master's thesis at the University of Tehran entitled "Linear astrolabe: description, structure and usage", comprising a Persian translation of, and commentary on the texts by al-Ṭūsī and Ibn Yūnus. A critical edition of both treatises and an English version are not available yet. However, our knowledge is shortly to take a significant step forward with a forthcoming publication in English by the same author.

14 # On Sharaf al-Dīn al-Ṭūsī see the articles in *BEA* by Glen Van Brummelen and on the author see Suter, *Mathematiker und Astronomen*, no. 333; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 541. See also n. 100 below.

15 # On Kamāl al-Dīn ibn Yūnus see the articles in *DSB* by Roshdi Rashed and in *Encyclopaedia of Islam*, 2nd edn., by David Pingree; not in *BEA* (!); King, *Cairo Survey*, no. G13; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 576. See also n. 99 below.

mention (1) the celestial sphere, (2) the plane astrolabe, and (3) the linear astrolabe, and, rather charmingly, he also discussed the futility of trying to represent the celestial sphere at a point. We can be confident that he was citing Kamāl al-Dīn ibn Yūnus on this.

The medieval Arabic texts on the spherical astrolabe

Several Arabic treatises were written on the spherical astrolabe between the 9th and 17th centuries. In 1925 Hugo Seemann and Theodor Mittelberger produced a splendid study of all the available sources known to them, concentrating on the information in the late-13th-century *Libros del saber de astrología* but including discussions of four earlier Arabic texts.[16] New treatises have become available since then, mostly, as we shall see, in the libraries of Istanbul. Most of the sources that are now available have been surveyed by François Charette,[17] to which we can add an early treatise by al-Wāsiṭī and another later one possibly by Sharaf al-Dīn al-Khalīlī (see below) and more information provided by Julio Samsó on the Alfonsine tradition of al-Andalus. No independent Latin treatises are known from medieval Europe and no European spherical astrolabes.

A treatise by Ḥabash al-Ḥāsib, the most innovative Muslim astronomer of the 9th century, is supposedly extant in MS Istanbul Topkapı AIII 3475,2, fols. 79a-89a, copied in the 16th century. This would then be the earliest treatise on the instrument. However, This author has examined a photocopy of this manuscript: the treatise is anonymous, late, and singularly uninformative, and it has nothing to do with Ḥabash.[18] Nevertheless, al-Nayrīzī (see below) states that it was "al-Marwazī", from Marw in Central Asia, who had written a treatise on the spherical

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16 Seeman & Mittelberger, "Das kugelförmige Astrolab nach den Mitteilungen von Alfons X von Kastilien und der vorhandenen arabischen Quellen" (1925). This excellent overview is typical of a trend in Western scholarship dealing with the medieval period to study first the European sources and then the earlier Islamic sources on which they are based or by which they were inspired. Other examples of this trend, which continues to this day, could be named in the history of medieval astronomy.

17 Charette, *Mathematical instrumentation in 14th-century Egypt and Syria*, pp. 61-62.

18 # The treatise has been apparently studied by Prof. Hossam Elkhadem of Brussels, but has not been published.

astrolabe, and this can be none other than Abū Jaʿfar Aḥmad ibn ʿAbdallāh al-Marwazī, known as Ḥabash al-Ḥāsib.[19] The late Fuat Sezgin cites two other manuscripts of a treatise by Ḥabash, namely, Istanbul Aya Sofia 1654 (fols. 100v-105v, copied in the 17th century), and Tehran Aṣghar Mahdawī 503,3 (6 fols., copied in the 18th century), which are not currently accessible to me but which could be very important.

Several dozen manuscripts are available of a treatise in more than a single recension by the late-9th-century philosopher-scientist Qusṭā ibn Lūqā.[20] It was translated into Latin, Hebrew, Spanish and Italian in the Middle Ages. It was through these translations that the instrument became known in medieval Europe, although no independent treatises survive and no examples either.

A well-organized treatise by al-Nayrīzī, a renowned astronomer and mathematician of the late 9th century,[21] was analyzed with that of Qusṭā by Seemann and Mittelberger in 1925, with a German translation of the

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19 On Ḥabash see the articles by Sevim Tekeli in *DSB* and by François Charette in *BEA*, and now the article by Julio Samsó in *Encyclopedia of Islam Three*. Some of his achievements are mentioned in the web-page Zaimeche, "Merv: History, Science and Learning", On the manuscripts see Krause, "Stambuler Handschriften islamischer Mathematiker", pp. 446-447 (no. 22); Sezgin, *Geschichte des arabischen Schrifttums*, VI, p. 175; Charette, *Mathematical instrumentation in 14th-century Egypt and Syria*, p. 61.

See also Charette & Schmidl, "A universal plate for timekeeping with the stars by Ḥabash al-Ḥāsib", on a sophisticated universal device by Ḥabash for timekeeping at night. It has been shown that the 14th-century English *navicula*, a universal device for timekeeping by the sun and the most sophisticated trigonometric device known in Europe at the time, was probably also invented by Ḥabash: see King, *In Synchrony with the heavens*, XIIb "On universal horary dials for timekeeping by the sun and stars", pp. 259-336, esp. pp. 285-299.

20 On Quṣṭā see the article in *BEA* by Elaheh Kheirandish. On this treatise see Sezgin, *Geschichte des arabischen Schrifttums*, VI, p. 180-182, esp. p. 181, no. 1; Charette, *Mathematical instrumentation in 14th-century Egypt and Syria,* p. 62; and most especially Seemann & Mittelberger, "Das sphärische Astrolab ... ", pp. 46-50. On a Latin version see Poulle, "L'astrolabe sphérique dans l'occident latin".

21 On al-Nayrīzī see the articles by A. I. Sabra in *DSB* and by Greg DeYoung in *BEA*; on the manuscripts see Sezgin, *Geschichte des arabischen Schrifttums*, VI, pp. 191-192.

introduction.[22] The Arabic text of the treatises of by al-Nayrīzī and Ḥāmid al-Wāsiṭī with an Italian translation and commentary was published by Ornella Marra in 2002.[23] Marra produced the first comprehensive overview of the situation regarding the manuscripts of the various treatises. She showed clearly that al-Wāsiṭī's text was closely related to, but much abridged from al-Nayrīzī's text.

Ḥāmid al-Wāsiṭī (*ca*. 950)[24] and the better-known Nasṭūlus (*ca*. 925)[25] were the two major instrument-makers in the Baghdad of their time. Ḥāmid's treatise on the spherical astrolabe, arranged in five introductory chapters and two parts of 57 and 20 chapters, is extant in MS Istanbul Topkapı Ahmet III 3509,2 (fols. 261a-281a, copied 676 Hijra (1278/79)) has been published by Ornella Marra (see above), who has shown that this treatise is heavily dependent on that of al-Nayrīzī (see below). Ḥāmid sings the praises of the spherical astrolabe over the planispheric astrolabe, stating that its construction does not require calculation or tables.[26] Indeed, as we shall see, most of the markings that need to be engraved on the sphere of a spherical astrolabe are concentric circles, and the star-tables

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22 Seemann & Mittelberger, "Das sphärische Astrolab ... ", pp. 32-40.

23 Marra, *L'astrolabio sferico ed il suo uso ... attribuito ad al-Nayrizi.*

24 On al-Wāsiṭī see Suter, *Mathematiker und Astronomen*, no. 76; Krause, "Stambuler Handschriften islamischer Mathematiker", pp. 458 (no. 76); Sezgin, *Geschichte des arabischen Schrifttums*, VI, p. 207. On two astrolabes by Ḥāmid see King, *In Synchrony with the Heavens*, XIIIc: 496-500 ("The earliest astrolabes from Iraq and Iran (*ca*. 850 – *ca*. 1100)).

25 On Nasṭūlus see the article by Mònica Rius in *BEA* (the name Basṭūlus is to be suppressed), and on his surviving instruments see King, *Synchrony*, XIIIc: 470-484 ("The earliest astrolabes from Iraq and Iran (*ca*. 850 – *ca*. 1100)); *idem*, "An instrument of mass calculation made by Nasṭūlus in Baghdad *ca*. 900", and *idem*, "Two newly-rediscovered astrolabes from Abbasid Baghdad". The discussion in Sezgin, *Geschichte des arabischen Schrifttums*, VI, pp. 178-179, is confused and even calls into question the authenticity of Nasṭūlus' astrolabe dated 315 H (927), in a way typical of scholars who deal only with texts. In July 2018 yet another genuine astrolabe attributable to Nasṭūlus came to light.

The name Nasṭūlus was misread as Basṭūlus in the 1970s and entered the popular literature in this incorrect (and impossible) form. He is now called Bitolus on the internet.

26 On Islamic tables for astrolabe construction see King & Samsó & Goldstein, "Astronomical handbooks and tables", pp. 91-92.

required (with ecliptic coordinates) are simpler than those for standard astrolabes (with equatorial coordinates). His opening remarks are these as follows:

اما هذا الاسطرلاب المسطح فإن الكري يفضل عليه في عمله وعلمه فإن الكري غير محتاج الى الحساب والجداول والعمال الصعبة المستخرجة بالهندسة اللتي ربما عرض فيها الزلل والخطآ ...

> "The spherical astrolabe is preferable to the plane astrolabe in its operations and its underlying theory because the spherical variety does not require any calculations or tables of coordinates or difficult operations derived by geometry in which mistakes and errors may perhaps occur. ..."

The 10th-century encyclopedist Abū ʿAbdallāh al-Khwārizmī mentions the spherical astrolabe briefly in his overview of astronomical instruments. He is not to be confused with the early-9th-century astronomer (and mathematician) Abū Jaʿfar Muḥammad ibn Mūsà al-Khwārizmī.[27]

A fragment of an early anonymous treatise survives in MS Mumbai Mulla Firuz 86, a gold-mine of early texts, and deserves investigation.[28]

The great al-Bīrūnī, multi-facetted scientist and polymath of Ghazna in the early 11th century, was familiar with the works of his predecessors in 9th- and 10th-century Baghdad. He mentioned the spherical astrolabe in his splendid book كتاب استيعاب الوجوه الممكنة في صنعة الاسطرلاب , *Kitāb Istīʿāb al-wujūh ṣanʿat al-asṭurlāb*, "A book containing a detailed discussion of different methods of constructing astrolabes", which includes various kinds of astrolabes and is a work that merits being translated into a Western language.[29] In passing al-Bīrūnī mentioned that he had actually seen a spherical astrolabe made by Jābir ibn Sinān (al-Ḥarrānī), probably

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27 Maddison, "15th century spherical astrolabe", p. 102.

28 Charette, *Mathematical instrumentation in 14th-century Egypt and Syria,* p. 62.

29 On al-Bīrūnī see the article by E. S. Kennedy in *DSB*; Sezgin, *Geschichte des arabischen Schrifttums*, VI, pp. 261-276, esp. p. 268; and Charette, *Mathematical instrumentation in 14th-century Egypt and Syria,* p. 62. A detailed account of his works and the available manuscripts and editions by Jan Hogendijk, dedicated to Ted (E. S.) Kennedy (1912-2009), Boris Abramovich Rosenfeld (1917-2008), and Abdulfattokh Rasulov (1888-1977), three outstanding scholars on al-Bīrūnī, is available at www.jphogendijk.nl/biruni.html.

in the late 9th century; this, however, did not have a rete, but functioned somehow with just an ecliptic ring.[30]

al-Bīrūnī writes in positive terms about the spherical astrolabe, although he obviously prefers the standard astrolabe. Here is a free translation of his introduction:[31]

> "On the construction of the spherical astrolabe with a rete and other(forms of the instrument). I say that the spherical astrolabe, even though its construction is easy and it does not require the concepts we presented (such as stereographic projection and plates for different latitudes), the plane astrolabe has obvious advantages (مزية ظاهرة , *mazīya ẓāhira)* because it is easy to carry on journeys, and it can be stored in places where one cannot carry the spherical (astrolabe) such as in sleeves and pockets and inside one's slippers or the pluck of a girdle, and so on. At the same time, it can withstand powerful, damaging knocks, which is not the case with the spherical (astrolabe) even with the slightest blow, knock or fall. On the other hand, it is the spherical astrolabe which represents the heavens and the form of its motions more easily than the plane astrolabe (إلا أن تصور ما في الفلك وهيئة حركاته يسهل من هذا ويصعب من ذلك , *illā 'an taṣawwur mā fi 'l-falak wa-hay'at ḥarakātihi yashalu min hādhā wa-yaṣʿabu min dhālika*)."

We leave the Arabic sources for a moment to consider the late-13th-century *Libros del saber de astrología* compiled in Toledo for King Alfonso X of Castille which also includes a treatise in Old Castillian on the spherical astrolabe (*astrolabio redondo*) that is splendidly illustrated. A detailed study of this was published by Seemann and Mittelberger in 1925, with a German translation of the introduction, and an English overview has recently been prepared by Julio Samsó.[32] The part on the construction

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30 Sezgin, *Geschichte des arabischen Schrifttums*, VI, p. 162.

31 I have used MS London British Library Or. 5593 (89 fols., copied in 614 H (1217), fol. 49e) of the استيعاب , *Istīʿāb*, available on the internet at www.qdl.qa/en/archive/. The first translation by Seemann & Mittelberger (German) was used by Sezgin (German, English, French and Arabic).

32 Seemann & Mittelberger, "Das sphärische Astrolab ... ", pp. 1-31, and Samsó, "The spherical astrolabe", §4.1.2 of his as yet unpublished *History of medieval astronomy in the Iberian Peninsula and the Maghrib*. See also Savage-Smith, *Islamicate celestial globes*, pp. 82-83, on the construction of the sphere in this treatise.

of the instrument is not a translation but an original work by the Jewish scholar Isaac ben Sid known as Rabiçag, since King Alfonso could not find a source describing how the instrument should be made and he asked Rabiçag to write the book on how to construct it. There is no written evidence concerning the second part of the book which deals with the use of the instrument, but it was probably also authored by Rabiçag himself or by another of the scientific collaborators of Alfonso X. This part is extremely long, containing 135 chapters, of which 110 are either literal translations, summaries or adaptations of the treatise on the planispheric astrolabe by the Andalusī astronomer Ibn al-Samḥ *ca*. 1100.[33] (See below on the star-table in this work.)

In Cairo around 1280 the astronomer of Moroccan origin Sharaf al-Dīn Abū ʿAlī al-Marrākushī discussed the spherical astrolabe in his monumental *summa* dealing with astronomical instruments.[34] He relied heavily on al-Bīrūnī. al-Marrākushī's work was very influential in Egypt, Syria and Turkey over the next five centuries.

In Cairo around 1325 the rather enigmatic astronomer Najm al-Dīn al-Miṣrī compiled a book describing some 100 varieties of instruments that were known to him or that he had invented himself. This treatise has been published, translated and commented upon in an exemplary fashion by François Charette.[35] In his brief discussion of the spherical astrolabe Najm al-Dīn states that the rete cannot be depicted on the page because it is spherical, and he would have been mightily impressed by the illustrations in the *Libros del saber*.

The anonymous treatise in 25 chapters (*bāb*s) on the spherical astrolabe in MS Istanbul (Sülymaniye) Hamidiye 1453 (fols. 213v-219r, copied in 869 H (1464/65)), is probably, as I argued some 40 years ago, a 14th-century

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33 On Ibn al-Samḥ see the article by Mònica Rius in *BEA*.

34 On al-Marrākushī see my article in *Encyclopaedia of Islam*, 2nd edn., and for a reassessment of his writings on instruments see François Charette's article in *BEA*, and also *idem*, *Mathematical instrumentation in 14th-century Egypt and Syria*, pp. 9-13. The relevant text can be found in MS Istanbul Topkapı Ahmet III 3343, facsimile published in Frankfurt, 1984, vol. II, pp. 8-14, French translation in Sédillot-*fils*, *Mémoire sur les instruments astronomiques des arabes*, pp. 142-148.

35 On Najm al-Dīn see the article in *BEA* by François Charette. For his discussion of the spherical astrolabe see *idem*, *Mathematical instrumentation in 14th-century Egypt and Syria,* pp. 62 and 259 (Ch. 25).

Syrian compilation, perhaps by Sharaf al-Dīn Mūsà al-Khalīlī, author of various instrument treatises.[36] Taha Yasin Arslan, writing now on the importance of MS Hamidiye 1453, a collection of Mamluk and early Ottoman astronomical works of considerable historical importance, prefers an Ottoman provenance for this particular treatise, with the copyist ʿUmar ibn ʿUthmān ibn ʿUmar al-Ḥusaynī al-Dimashqī al-Asṭurlābī as author.[37] This is certainly feasible although al-Dimashqī might have said that he was the author. The actual author states that in his introduction that he "spent ample time learning how to make quality and beautiful instruments and finally mastered the art of globe making". A treatise in 20 chapters on the use of the spherical astrolabe in Persian – *Risāla dar maʿrifat-i asṭurlāb-i kurī* – was compiled by Hoja ʿAṭā' Allāh ibn ʿAbdallāh al-ʿAjamī (d. 1499/1500), a scholar of Iranian origin who spent his later years in Istanbul.[38] We shall return to these treatises below.

A treatise on the كرة الاسطرلاب , *kurat al-asṭurlāb*, "sphere of the astrolabe", preserved in a Rabat manuscript and attributed to the astronomer Ibn al-Raqqām of Tunis *ca*. 1300 (see Section 3) has nothing to do with the spherical astrolabe.[39]

A late Maghribī treatise on the spherical astrolabe written by Ibrāhīm ibn ʿAlī al-Andalusī al-Marrākushī (d. 1727) has not been studied.[40]

A rather strange spherical instrument was invented and described by a 17th-century Medinan scholar Muḥammad ibn Muḥammad ibn Sulaymān

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36 # On Sharaf al-Dīn Mūsà al-Khalīlī see King, *Cairo Survey*, no. C38; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 797. On this treatise see King, "Origin of the astrolabe in the Arabic sources", pp. 57, and p. 597 of the version in *Synchrony*, vol. 2. See also n. 102 on the author see Suter, *Mathematiker und Astronomen*, no. 333; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 541. below.

37 Arslan, "ʿUmar al-Dimashqī and his *'ilm al-mīqāt* corpus – the Hamidiye 1453" (2018), p. 134 and n. 30.

38 *Ibid*., p. 134, n. 30, and İhsanoğlu *et al*., *Ottoman astronomical literature*, I, pp. 66-67.

39 The MS (Rabat General Library 4155) is mentioned in Rosenfeld, "*MAIC* supplement two", p. 16, no. 670. Prof. Julio Samsó has inspected it and assures me that it does not deal with the spherical astrolabe.

40 Samsó, "Spherical astrolabe".

al-Rūdānī. The Arabic text and a French translation were published by the French Arabist Charles Pellat in 1973 with a commentary by the sundial-specialist Louis Janin in 1978.[41] Pellat unfortunately referred to al-Rūdānī's instrument as a spherical astrolabe; al-Rūdānī himself had called it simply الجامعة , *al-jāmiʿa*, "the universal, or the all-embracing (instrument)". Pellat's label stuck, so that when the only known example of al-Rūdānī's instrument, made by him in Medina in 1073 H (1662/63), was auctioned at Christie's in London in 2015, it was presented as a "spherical astrolabe", following Pellat, without any indication that this was an inappropriate description, and certainly not what al-Rūdānī himself had called it.[42] In fact, al-Rūdānī embellished the basic spherical instrument with a world-map and various trigonometric scales and provided a simple hemi-spherical rete.

From this brief overview it is clear that there is work to be done on these texts. An overview of the whole corpus could indeed constitute a topic for a doctoral dissertation. A new contribution has been made already by the late Fuat Sezgin and his staff in Frankfurt, who have produced models of the instruments described in the principal texts and a copy of the Oxford spherical astrolabe (see further below), illustrated with extracts from the published literature.[43] Most of the Sezgin's text is derived from the extensive study of Seemann and Mittlberger, excellent in its time and still the main study on the spherical astrolabe, but it contains little of consequence that is new and in general it should be used with caution. Also, the treatises of Ḥabash al-Ḥāsib and Ḥāmid al-Wāsiṭī are overlooked.

The climates of classical and medieval geography

We shall have occasion to mention the geographical climates, and a few words may be appropriate to introduce this notion which is little understood in many modern writings. The Muslims inherited the Greek tradition of dividing the inhabited world, the *oekoumene* (οἰκουμένη), into

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41 See Pellat and Janin in the bibliography. An overview based on the texts is in Samsó, "Spherical astrolabe". On al-Rūdānī see the article in *BEA* by Salim Ayduz.

42 https://www.christies.com/lotfinder/Lot/a-rare-and-important-spherical-astrolabe-signed-5930901-details.aspx (08.10.2015). It sold for close to £725,000.

43 Sezgin & Neubauer, *Science and technology in Islam*, II, pp. 120-133. The text is also available in German, French and Arabic.

seven latitudinal strips known as 'climates' (إقليم، ج. أقاليم , *iqlîm*, pl. *aqâlîm*). The beginnings, middles and ends of these were defined by the length of longest day, increasing by $^{1}/_{2}$ hour for each climate, and starting from the first climate with beginning at $12^{3}/_{4}{}^{h}$, middle at 13^{h} and upper limit at $13^{1}/_{4}{}^{h}$. Thus the middles of the climates (hereafter C1-C7) are defined as follows, thus:

C1	C2	C3	C4	C5	C6	C7
13^{h}	$13^{1}/_{2}$	14	$14^{1}/_{2}$	15	$15^{1}/_{2}$	16 .

The lower and upper limits of the climates are appropriately defined by $^{1}/_{4}$ hour less or more than the lengths at the middle. The latitudes of the climates rounded to the nearest degree are:

C1: 16°	C2: 24°	C3: 30°	C4: 36°	C5: 41°	C6: 45°	C7: 48°.

Quite by chance certain localities of significance in the history of ancient and/or medieval astronomy lie close to the midpoints of the climates, namely: the Yemen (C1); Syene (modern Aswan) (C2); Alexandria / Cairo (C3); Rhodes / Raqqa / Rayy (near modern Tehran) (C4); Constantinople / Toledo / Catalonia (C5); the Po Valley (C6); and Paris / Vienna / Nuremberg (C7). This fortunate situation partly accounted for the popularity of the climates amongst medieval instrument-makers, Muslim and Christian alike. Indeed, the climates are of paramount importance for understanding the geography of medieval Islamic and European astrolabes and other instruments, and they have not received the attention they deserve in modern writings either on medieval geography or medieval instrumentation or indeed on medieval astronomy in general.[44]

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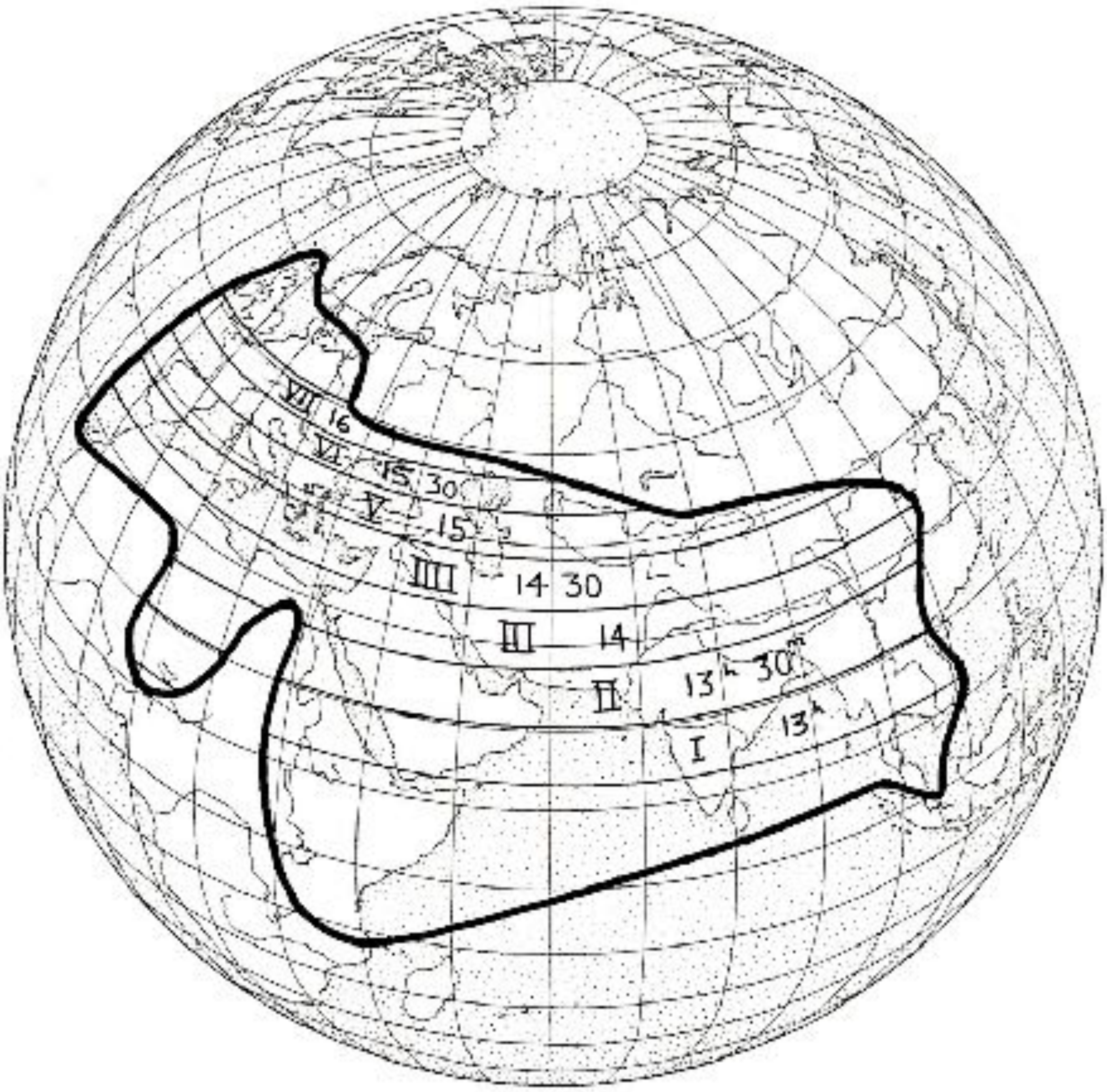
44 See, for example, Gunther, *Astrolabes of the World*, pp. 65 and 83, for the relevant passages in the treatises of Philoponus (*ca*. 530) and Severus Sebokht (before 660). On the climates in Antiquity the standard source is Honigmann, *Die sieben Klimata*; see also Neugebauer, *HAMA*, II, pp. 725-733. The climates in the Islamic geographical sources are briefly treated in the article "Iḳlīm" by André Miquel in *Encyclopedia of Islam*, 2nd edn.

More detailed studies of the climates in Islamic geography, astronomy and instrumentation are J. T. Olsson, "A reassessment of the climes in medieval Islamic scholarship"; Dallal, "Al-Bīrūnī on climates"; King, *World-maps*, pp. 27-28, 230-234, 432; *idem*, *In Synchrony with the Heavens*, XVI: "The geographical data on early Islamic astronomical instruments", pp. 915-962, esp. 925-932, *etc*. Ganji, article "Climes", in *Encyclopaedia Islamica* (2018), is a substantial article but does not deal with literature on geographical tables or instruments.



The climates of Antiquity shown within the boundaries of the world as known to Ptolemy. The influence of the climates in medieval geography, astronomy, and instrumentation has been much underestimated in modern scholarship. [Graphics courtesy of a student at Frankfurt University who left this with the author in the early 1990s without leaving his name.]

Since the climates are defined in terms of the length of longest daylight, they are dependent on the value assumed for the obliquity of the ecliptic, which changed slowly over the centuries. Ptolemy's value was 23°51´20´´ and the latitudes for the climates based on this are shown in the accompanying table, along with values for other popular values thereafter. Muslim astronomers commissioned by the Caliph al-Ma'mūn in the early 9th century measured the obliquity anew and came up with more up-to-date values of 23°33´ and 23°35´;[45] the latitudes of the climates would of necessity be different – see Table 1. Nevertheless, the Ptolemaic tradition was not abandoned forthwith, for many later Muslim astrolabists, even some Safavid and Ottoman ones, used, wittingly or not, Ptolemy's value.[46] If they had not, the latitudes of the climates would have 'changed' enough to be annoying, and the daylight values for newly-determined latitudes would have conflicted with the climate situation.

The climates have not always served their purpose, and they have sometimes confused medievals and moderns alike. The main problems are that:

- they are not equal in width, decreasing from almost 8° for C1 to almost 3° for C7; and
- the latitudes which can be associated with them vary slowly with time, some 20´ over 1500 years for C1 and 30´ for C7.

Change in these climates, in a non-detrimental sense, occurred already in Antiquity.

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45 For values used by Muslim astronomers see the article "Minṭaḳat al-burūdj̲" [= zodiac] in *Encyclopedia of Islam*, 2nd edn., originally by Willy Hartner, updated by Paul Kunitzsch, especially VII, p. 86. Determinations of the obliquity were of course related to determinations of the local latitude.

46 King, "The geography of astrolabes", pp. 21-27/948-957.

The latitudes of the midpoints and boundaries of the seven climates (C1-C7), defined in terms of the length of maximum daylight (D), for different values of the obliquity of the ecliptic (ε).

(Such a table is not found in the ancient or medieval sources, though see Dallal, "al-Bīrūnī on the Climates", for the most significant medieval discussion.)

C	D ε \	24;00°	23;51	23;35	23;33	23;31	23;30	23;28
	12;45ʰ	12;25°	12;30	12;39	12;40	12;42	12;42	12;43
C1	13;00	16;20	16;27	16;39	16;40	16;42	16;43	16;43
	13;15	20;06	20;14	20;28	20;30	20;31	20;32	20;33
C2	13;30	23;40	23;49	24;05	24;07	24;09	24;10	24;11
	13;45	27;01	27;11	27;29	27;31	27;33	27;35	27;36
C3	14;00	30;10	30;21	30;40	30;42	30;45	30;46	30;47
	14;15	33;0 6	33;17	33;37	33;40	33;42	33;44	33;45
C4	14;30	35;50	36;01	36;22	36;25	36;27	36;28	36;30
	14;45	38;21	38;33	38;54	38;57	38;59	39;01	39;02
C5	15;00	40;41	40;53	41;14	41;17	41;20	41;21	41;22
	15;15	42;50	43;02	43;24	43;26	43;29	43;30	43,32
C6	15;30	44;49	45;01	45;22	45;25	45;28	45;29	45;31
	15;45	46;38	46;50	47;12	47;15	47;17	47;19	47;20
C7	16; 0	48;19	48;31	48;53	48;55	48;58	48;59	49;01
	16;15	49;52	50;04	50;25	50;28	50;31	50;32	50;33

Note on the values of the obliquity ε: Indians: 24°; Ptolemy: 23;51° (rounded); Muslim astronomers (9th and 14th centuries): 23;33°; Muslim astronomers (9th century and thereafter): 23;35°; al-Ṭūsī (*ca*. 1250) and Ibn al-Shāṭir (*ca*. 1350): 23;31°; Ulugh Beg (*ca*. 1425): 23;30° (rounded); Ottoman astronomers (16th century and thereafter): 23;28°.

A single plate originally from a 9th-century astrolabe from Baghdad. This side serves the 3rd climate with latitude 30°, and the solar meridian altitude at the equinoxes is 60°. The other side has markings for the 2nd climate with latitude 24°. [Private collection, images courtesy of the owner.]

The inscription reads:
اقليم الثالث عرضه ل ساعاته يد ,
(*al-*)*iqlīm al-thālith ʿarḍuhu l sāʿātuhu yd*,
"the third climate – latitude is 30° and
(longest daylight) is 14 hours".

We find the climates represented explicitly or almost so on the sole surviving Byzantine astrolabe, on the earliest surviving Eastern Islamic astrolabes, on the earliest known Western Islamic astrolabe, as well as some of the earliest European astrolabes. Even on numerous later ones, they are often there implicitly. The medieval tradition of engraving the length of maximum daylight along with the latitude on astrolabe plates goes back to the notion of the climates.[47]

It may be of interest to consider some examples of confusion regarding the climates, not only in medieval practice but also in modern interpretations thereof.

Byzantine astronomers, for example, were not sure whether Constantinople was at the middle of the 5th climate or the 6th. So its latitude varied in Byzantine astronomical sources between *ca*. 41° and *ca*. 45°.[48] Ptolemy had put Hellespont or 'Byzantion' at *ca*. 43°, and most Islamic geographical tables situate it at 45°, but one early-14th-century Iranian table even has it at latitude 49° in the 7th climate.[49] The Byzantine astrolabe of 1062 has Hellespont at 40° and 'Byzantion' at 41°, both in the 5th climate, with Rhodes at 36° at the 4th climate.[50] Ottoman astronomers from the 15th century onwards used 41°, 41°15′, or 41°30′, which means that somebody had actually measured it, that is, had derived it by observation (usually of midday altitudes at the solstices and/or equinoxes). The first of these three values is the most accurate.[51] We have no information on the astronomers who derived these values, but it should be kept in mind that the Byzantine astrolabe of 1062 used 41° for the capital city some 400 years previously. A recent proposal that Fatḥallāh Shirwānī might be responsible for a new measurement is wishful thinking.[52]

The latitude 36° was favoured in Antiquity, notably by Hipparchus and Ptolemy, as an appropriate 'paradigm' value. Not only was it the latitude of

47 King, "Geography of astrolabes", *passim*.

48 King, "Notes on Byzantine astronomy", pp. 117-118.

49 Kennedy & Kennedy, *Islamic geographical coordinates*, pp. 93-94.

50 King, *Astrolabes and angels*, p. 229.

51 King, *In Synchrony with the Heavens*, II: "Turkish tables for timekeeping", 440-456.

52 Trigg, "Astronomical commentaries of Fatḥallāh al-Shirwānī", pp. 371-372.

Rhodes, where Hipparchus developed stereographic projection, but it was conveniently the latitude of the middle of the 4th climate, that is, the middle of the inhabited world.

Various Muslim astronomers adopted the same notion. The elusive Najm al-Dīn al-Miṣrī of Cairo (*ca*. 1325), in his remarkable treatise on over 100 instrument types known to him or invented by himself, used latitude 36° in some of his tables and latitude 48° in others and also in his illustrations of instruments.[53] These have nothing to do with, say, Aleppo with latitude 36°, or any northern locality with latitude 48°, but rather with the middle of the 4th climate and the middle of the 7th climate, respectively.

When an anonymous manuscript of Najm al-Dīn's treatise was first discovered in the Chester Beatty Library in Dublin in 1982, this author immediately announced it as a work of the celebrated Ibn al-Sarrāj of Aleppo (*ca*. 1325),[54] the maker of the most sophisticated astrolabe ever conceived, universal in five different ways and now preserved in the Benaki Museum. Athens. He came to this rash conclusion because all of the tables and illustrations of latitude-dependent instruments were for latitude 36°, therefore surely for Aleppo. When François Charette started working on this treatise for his doctoral dissertation he soon realized that the work was in fact by the Cairene astronomer Najm al-Dīn al-Miṣrī,[55] known to him already as the compiler of the largest astronomical table prepared in pre-modern times (*ca*. 440,000 entries). This was not only a universal table for timekeeping by the sun and stars, but in addition a universal table for solving all the problems of spherical astronomy for all latitudes.[56] But Najm al-Dīn's numerous tables in his instrument treatise were calculated not for Cairo with latitude 30° and not simply for latitude

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53 See, for example, Charette, *Mathematical instrumentation in 14th-century Egypt and Syria*, especially pp. 28, 324-326 and 330, for tables based on latitude 36°, and pp. 84, 225, and 293-294, for instruments and tables for latitude 48°.

54 For a detailed description see King, *In Synchrony with the Heavens*, XIVb "Some astronomical instruments from medieval Syria": 694-700. For a shorter notice see *idem*, *Islamic astronomy and geography*, III, pp. 154 and 158-159.

55 Charette, *Mathematical instrumentation in 14th-century Egypt and Syria*, pp. 24-31.

56 Charette, "A monumental medieval table for solving the problems of Spherical Astronomy for all latitudes" (1998), also King, *In Synchrony with the Heavens*, I "A survey of Islamic tables for timekeeping by the sun and stars": 167-168.

36° for Aleppo or anywhere specific,[57] but for latitude 36° as centre of the inhabited world, to be used for pedagogic purposes as *the* latitude.[58] This, of course, Najm al-Dīn does not mention.

In the tables of geographical coordinates in an Iranian astronomical handbook from *ca*. 1100 we find a locality named بلد الإقبال , *balad al-iqbāl*, the meaning of which is uncertain, at latitude 36°21′. This is now generally taken to refer to the Ismāʿīlī fortress of Alamut (actually at latitude 36°26′), where the work was supposedly compiled.[59] This does not mean that someone actually measured the latitude, accurately at that, but rather that somebody probably calculated it, not necessarily at Alamut, for it is the latitude of the middle of the 4th climate, derived for the value of the obliquity of the ecliptic accepted at the time. Some of the tables in this source are based on this latitude.[60]

An error which this author made in 2004 relates to a quartet of tables in a Persian astronomical handbook entitled *Zīj-i Ashrafī* compiled by Sanjar al-Kamālī, known as Sayf-i Munajjim, in Shiraz in the year 702 H (1302/03).[61] Values are stated in the unique manuscript to be for latitudes:

29°36′ 30°22′ 33°18′ 36°00′ .

The first of these is the latitude of Shiraz, also used elsewhere by Sayf-i Munajjim. The fourth was, I wrote, "standard for Rayy (near modern Tehran) and the 4th climate". The first and third, not attested elsewhere, must be, I claimed, for "two other cities in Iran". In fact, the latitudes of the climates for Ptolemy's value of the obliquity are:

C3: 30°21′ C3/4: 33°19′ C4: 36°01′ ,

so the second, third and fourth tables serve <u>any</u> cities on these parallels.

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57 King, *World-maps for finding the direction and distance to Mecca* (1999), p. xxix; and Charette, *Mathematical instrumentation in 14th-century Egypt and Syria*, p. 28.

58 King, *Islamic astronomy and geography* (2012), pp. ix-x. On Ibn al-Sarrāj and his instruments see King, *In Synchrony with the Heavens*, pp. 52, 61, 694-703.

59 Orthmann & Schmidl, eds., *Science in the City of Fortune*, pp. 29, 49, 55.

60 King, *In Synchrony with the Heavens*, II: 240-241 "A survey of tables for regulating the times of prayer".

61 King, *In Synchrony with the Heavens*, I: 157 "A survey of tables for timekeeping by the sun and stars".

Or take a very special medieval Italian astrolabe, unique of its kind amongst both Islamic and European astrolabes, which is preserved in the Museum of the History of Science at Oxford. Robert Gunther in his monumental *Astrolabes of the World* (1932) misinterpreted the unlabelled single set of markings on the mater as serving latitude 38°; thus the provenance was set for all time as 'Sicilian'.[62] In fact, the markings serve latitude 24°, that is Aswan. This tells us on the one hand that the astrolabe is non-functional anywhere in Europe, but also that these unhappy markings for the middle of the second climate must have been inspired by a set for each of the climates, so that we are dealing with a(nother) hitherto-unknown (Islamic) tradition of universal astrolabes.[63] The piece still may be Sicilian, but no serious astronomical instrumentation is known there except amongst Jewish scholars from the late 14th to late 15th century.[64]

The significance of the climates in instrumentation is underlined by the rediscovery of an astrolabic plate for latitude 16°27′ SOUTH from an 11th-century astrolabe made in al-Andalus, preserved inside an 18th-century Ottoman astrolabe. This would serve the middle of the first climate south of the Equator, Ptolemy's Anti-Meroë. It, like another plate for latitude 72°, could serve only didactic purposes.[65]

Several more instances could be cited of the use and misuse of the climates, but even more instances of their importance have been documented in the recent literature.

Universal or latitude-dependent?

Most of the texts tells us that the spherical astrolabe can be used for all latitudes, this by means of a latitude scale attached to the rete. But then the markings for the seasonal hours on the underside of the sphere, which serve a specific latitude, are superfluous. Yet more than one medieval instrument-maker has thought it appropriate to have both a universal latitude scale and a set of seasonal hour markings for a specific latitude. These are not mutually exclusive but if one is using the latitude scale for a

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62 Gunther, *Astrolabes of the World*, II, pp. 319-320 (no.169).

63 See King, "Remarkable Italian astrolabe".

64 Goldstein, "Descriptions of astronomical instruments in Hebrew".

65 King, "An Ottoman astrolabe full of surprises".

general latitude then one should not use the seasonal hour markings for a specific latitude. If one is using the seasonal hour markings for the specific latitude for which they are intended, one should make sure that the latitude scale is set at that particular latitude. The analogous situation for a planispheric astrolabe would be to use a standard plate for a specific latitude for all latitudes; one can only do that if the plate is latitude independent, which is one reason the markings for latitude 0° were basic to the development of the universal astrolabe. However, at that latitude the seasonal hours and the equinoctial hours are identical; for a spherical astrolabe the 'seasonal hour' markings for latitude 0° would be a family of 'parallel' arcs of co-axial great circles.

Now the spherical astrolabe for Tunis has an inscription stating definitively that the seasonal hour markings are for the latitude of Tunis, taken as 36°40′. Since it no longer has any rete we cannot know whether it had a universal latitude scale. Certainly someone has 'added' four sets of over-large holes, with diametrically-opposite counterparts, to indicate four specific latitudes, including two of practical use, for Mecca and Tunis, and two for pedagogical use, for the Equator and the Arctic Circle.

The spherical astrolabe in Oxford has no indication of the latitude underlying the seasonal hour markings, which are found by inspection to be for latitude *ca*. 41°. This generally serves the latitude of the 5th climate but also specifically Istanbul. There is no inscription to inform us of this, and only additional internal evidence can tell us more about the milieu in which it was constructed.

Now as we shall see, the 'new' spherical astrolabe has seasonal hour markings for a latitude of *ca*. 36°. This again has been determined by inspection. The latitude defines not only the middle of the 4th climate, but also the middle of the *oekoumene* (οἰκουμένη) or inhabited part of the Earth. Now latitude 36° was chosen by astronomers in Antiquity and the Islamic Middle Ages as the most important latitude for pedagogical purposes. The great Hipparchos of Rhodes (*ca*. 150 BCE) had the good fortune that Rhodes lies (at latitude 36°) at the middle of the 4th climate.[66] In fact, in the Arabic translation of Ptolemy's *Planisphaerium* (كتاب في تسطيح بسيط الكرة , *Kitāb fī Tasṭīḥ basīṭ al-kura*, *Book on flattening the*

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[66] Neugebauer, *History of Mathematical Astronomy*, I, pp. 725 ff. For a new study see Shcheglov, "Hipparchus' table of *climata* and Ptolemy's *Geography*".

surface of the sphere or *Book on stereographical projection*),[67] Ptolemy introduces some of his numerical examples in the following terms, associating latitude 36° with Rhodes although he was writing in Alexandria:

> ونستعمل ايضا على طريق المثال الدائرة الموازية لمعدل النهار التي استعملنا في كتاب المجسطي أعني الدائرة التي تمر بجزيرة رودس وارتفاع القطب الشمالي في هذه الدائرة عن الافق ست وثلاثون درجة
>
> "By way of example, we again use the circle parallel to the equator that we used in the *Almagest*, namely the circle that passes through the island of Rhodes. In this circle, the height of the (celestial) north pole above the horizon is 36°."

The modern editors of this text, Nathan Sidoli and Len Berggren, label this the "paradigm latitude", and so it remained for well over a millennium.

We shall eventually learn why the maker of the 'new' spherical astrolabe chose latitude *ca*. 36° for his instrument.

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67 Sidoli & Berggren, "Arabic version of Ptolemy's *Planisphere*", pp. 52, 62 & 67 (Arabic), and 90 & 95 (translation); it is specifically associated with Rhodes.

2 The anonymous spherical astrolabe made for Tunis

> "The present note describes a globe which appears to be the main body of a West Islamic spherical astrolabe. Until the identification of this globe a few months ago, the unique example of a spherical astrolabe apparently was the Eastern Islamic instrument acquired in 1962 by the Museum of the History of Science at Oxford." Ernesto Canobbio, "An important fragment of a Western Islamic spherical astrolabe" (1976), p. 37.

In a European private collection there is a remarkable spherical astrolabe with Arabic inscriptions. It is alas incomplete, for the hemispherical rete is missing. It is unsigned, or at least there is no maker's name engraved on the spher. It had been in the possession of the family of Ernesto Canobbio of Como since the first half of the 20th century, as an antique whose importance had not been recognized.

This spherical astrolabe was dutifully published in 1976 by its owner, Ernesto Canobbio,[68] taking into consideration Francis Maddison's description of the spherical astrolabe in Oxford University's Museum of the History of Science (see below). Both these instruments were exhibited together at London's Science Museum in the context of the fateful so-called 'World of Islam Festival' exhibitions in 1976.[69]

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[68] Canobbio, "Fragment of a West Islamic spherical astrolabe".

[69] The catalogue of scientific instruments prepared by Francis Maddison and Anthony Turner was alas never published. It could have provided an enormous boost to our subject. The spherical astrolabes are mentioned in the unpublished manuscript *Catalogue of an Exhibition 'Science and Technology in Islam' ...* , 1976, nos. 68-69, summarized in the 'Exhibition guide'. The sole legacy of the exhibition for the history of Islamic science was a beautifully illustrated book Nasr, *Islamic Science – An illustrated study* (1976), alas singularly uninformed on Islamic astronomy and mathematics, but which was also singularly successful in initiating a new age in the popularization of the history of Islamic science based on half-truths and distortions.

Dimensions and weight

The diameter is 115 mm and the weight 225 g. The two halves of the sphere have been welded together and cannot be separated.

The inscription

By the side of the markings for the seasonal hours on the lower half of the sphere we find the inscription:

ساعات عرض تونس وكل بلد عرضه لو م

sāʿāt ʿarḍ Tūnis wa-kulli balad ʿarḍuhu l-w m,

"the hours for the latitude of Tunis and
every locality whose latitude is 36°40′".

This is one of the standard formulae used on the latitude plates of planispheric astrolabes, and it does not matter that there are no significant localities besides Tunis which have that particular latitude. All the numbers on the three spherical astrolabes that we shall discuss are in Arabic alphanumerical notation, called *abjad* (ابجد = 'a,b,c,d' = 1,2,3,4), as was standard in Islamic astronomical tables and on astronomical instruments from the 8th century to the 19th.[70]

70 # Irani, "Arabic numeral notation" (1956). See also n. 270 below on the errors that can occur in this system.

The sphere

The sphere is made in two halves, now welded to each other and inseparable. The base of the upper half is to be considered as the horizon. Above the horizon there are altitude circles[71] for each 6° up to the zenith. These are labelled 6° - 12° - 18° - ... - 84° at each of the four quadrants, then no more altitude circle till 90°. There are also azimuth semi-circles for each 10° around the horizon labelled 10° - 20° - 90° in each of four quadrants starting at the east and west points. There is also a small hole of diameter 1 mm at the top of the sphere; its function is unclear. The four sets of pairs of diametrically-opposed holes in upper meridian circle are later 'additions' and will be treated as such below.

On the lower hemisphere we find first of all the lower halves of the meridian, labelled خط الزوال , *khaṭṭ al-zawāl*, and, perpendicular to it, the prime vertical. Then there are three parallel arcs of circles spanning the meridian. The small circle closer to the north is the Tropic of Cancer; the small circle further from the north is the Tropic of Capricorn. The great circle arc in the middle is the celestial equator. Arcs of small circles have been drawn between the one-twelfth divisions of the solstitial circles: these represent the seasonal hours, labelled from 1 to 12.

To determine roughly the latitude for which these markings were engraved is, as Ernesto Canobbio has written, a "*jeu d'enfant*", not least in this case where know what the maker intended. But given the size of the sphere, and the fact that the altitude circles are engraved only for each 6°, it is not possible to give a realistic value to closer than 1°-2°, so we can settle for *ca*. 37°. The inscription – see above – has already informed us that the markings were intended for 36°40′.

The times of the twilight prayers – (مغيب ال-) شفق , (*mughīb al-*) *shafaq* for the end of evening twilight and (طلوع ال-) فجر , (*tulūʿ al-*) *fajr* for daybreak – and the two daylight prayers whose times are defined in terms of shadow-lengths – ظهر , *ẓuhr* after midday (according to the distinctive Maghribī and Andalusī definition) and عصر , *ʿaṣr* roughly at mid-

[71] The expressions 'altitude circles' is used so as to avoid the unhappy term 'almucantars', from Arabic المقنطرات , *al-muqanṭarāt*, which people, even those with Arabic as their first language, do not understand any more. Similarly the expression 'azimuth circles' is used, although few understand it anyway, even though 'azimuth' is derived from Arabic السموت , *al-sumūt*, pronounced *as-sumūt*, plural of سمت , *samt*, direction.

afternoon – are marked with hatched curves.[72] The altitude circle for 18° is also hatched, since the duration of twilight for a given solar longitude at this latitude can also be found using this circle together with the opposite solar longitude. The markings for the hours are for a specific latitude – in this case, 36°40′ – as on the other two spherical astrolabes discussed below. Likewise, these additional markings for the prayers are latitude-dependent and hence are not universal. The instrument can be used at any of the four latitudes mentioned above, but the curves for the seasonal hours and the prayer-times cannot.

The astronomical markings and the engraving, in Maghribī *kūfī*, on this Tunisian instrument are somewhat more carefully executed than on either of the Oxford example (described below). The author can confirm that it is from the 14th or the early 15th century.

Later modifications

We shall never know whether there was a latitude scale on the now missing rete? There are, however, on the sphere four rather large holes on the quadrant which have been added later. In some places the holes have removed parts of the original inscriptions on the scales. The holes correspond to latitudes:

~21°30′ (Mecca) and ~36°40′ (Tunis) as well as
0° (equator) and ~66°30′ (Arctic Circle).

(We have already commented on the latitude 36°40′; here we mention that the value 21°30′ for Mecca was first derived in mid 9th century, it is not known by whom,[73] but the value is here estimated. The accurate value is 21°26′.) The holes are circular with a protrusion on the left so that they resemble key-holes. There are four similar holes diametrically opposite, that is, on the empty half of the lower hemisphere.

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72 On the prayer-times in Islam see my article "Mīkāt. ii. Astronomical aspects" in *Encyclopaedia of Islam*, 2nd edn., repr. in *idem*, *Astronomy in the service of Islam*, V, and *idem*, *In Synchrony with the Heavens*, vol. 1, IV: 529-622 "The times of Muslim prayer" (where the origin of the definitions of the day-light prayers in terms of shadow increases is explained); II: 191-456 "Survey of tables for regulating the times of prayer"; and vol. 2, *passim*, for markings for the prayer-times on instruments.

73 See King, "Earliest Muslim geodetic measurements", pp. 225-226.

It would be interesting to know what the person responsible for these holes had in mind with them. (Clearly, a keeled tube could made to fit through any of the four holes on one side, emerging from the diametrically opposed hole on the other; thus one can look straight through the sphere for example at a star in the night sky which would otherwise be obscured by the sphere itself. The ‘keel’ on the tube would fit in the protrusion of the hole and stops the sphere from spinning around the access of the tube, staying firmly in place as one looks through it. In this case, some device, necessarily unwieldy, would need to be added to the tube to assist in measuring the solar or stellar altitude, one of which is necessary in order that the instrument be used.)

3 Remarks on astronomy in medieval Tunis

It is not generally known that there was a vibrant tradition of astronomy in Tunis and elsewhere in the province of Ifrīqiya, roughly equivalent to modern Tunisia, during the medieval period. For a start the renowned 10th-century Jewish astronomer Dūnash ibn Tamīm was already active in Kairouan in the 10th century.[74] At the beginning of the 11th century the famous astrologer of Kairouan Ibn Abī al-Rijāl al-Qayrawānī composed a *zīj*, or astronomical handbook with tables, which, unfortunately, has been lost.[75] There was considerable serious astronomical activity in Tunis itself in the 13th and 14th centuries and this latitude 36°40′ is an established medieval value for the city (accurately 36°50′). We have already mentioned the astronomer Ibn al-Raqqām, to whom a treatise on the spherical astrolabe has been attributed in error.

Ibn Isḥāq al-Tūnisī and his astronomical handbook

> "Contemporary Maghribi scholars are using as their reference work the astronomical handbook with tables (*zīj*) ascribed to Ibn Isḥāq." Ibn Khladūn, *al-Muqaddima*, quoted in King, "History of astronomy in the medieval Maghrib", p. 181.

The astronomer Ibn Isḥāq al-Tūnisī flourished in Tunis and Marrakech at least during the period 1193-1222.[76] He left an unfinished *zīj* (an astronomical handbook with tables) with a few canons and instructions for

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74 See Sezgin, *Geschichte des arabischen Schrifttums*, VI, pp. 196-197; Stern, "A treatise on the armillary sphere by Dūnash ibn Tamīm"; King, "Astronomy in the Maghrib", p. 180; Samsó, *History of Medieval Astronomy in the Iberian Peninsula and the Maghrib*, §5.2.1, *etc*.; most recently Y. Tzvi Langermann's article in *BEA*. In his treatise on the armillary sphere he mentioned his teacher, the astrolabist Abū ʿAlī Aḥmad ibn ʿUthmān al-Asṭurlābī.

75 See the article "Ibn Abi 'l-Ridjāl" in *Encyclopedia of Islam*, 2nd edn., by David Pingree, also Sezgin, *Geschichte des arabischen Schrifttums*, VII, pp. 186-188.

76 On Ibn Isḥāq see the article by Julio Samsó in *BEA*. This section of my paper is slightly modified, unabashedly, from Julio Samsó's article. On his *Zīj*, of which a Tunisian recension of the incomplete original is extant in a manuscript in Hyderabad (Andhra Pradesh State Library 298, copied in Homs in 1317), see Mestres, "Maghribī astronomy in the 13th century", and *idem*, *Materials Andalusins en el Zij d'Ibn Ishaq al-Tunisi*. For the context see King & Samsó & Goldstein, "Islamic astronomical handbooks and tables", pp. 60-62.

their use; this marked the first of a family of Maghribī astronomical works of this kind. The *zīj* was heavily influenced by the Toledan astronomer Ibn al-Zarqālī.[77] Until recently the only known references to Ibn Isḥāq were from

(1) the famous historian Ibn Khaldūn (1332–1382), who says, in his *Muqaddima*, that Ibn Isḥāq was an astronomer at the beginning of the 13th century who composed his *zīj* using (his own) observations as well as the information he obtained through correspondence with a Sicilian Jew who was competent in astronomy and a good teacher; and

(2) Ibn al-Bannāʾ al-Marrākushī (1256–1321) who states that Ibn Isḥāq made observations in Marrakesh, and that some of his tables were calculated for the year 1222.

Much more information on Ibn Isḥāq has been gathered after the discovery in 1978 of MS Hyderabad Andhra Pradesh State Library MS 298, copied in Homs (Syria) in 1317, which contains the most important collection of materials, including some 360 tables, derived from Ibn Isḥāq as well as from other (mainly Andalusī) sources. This compilation was made by an anonymous Tunisian astronomer who flourished *ca*. 1267-1282. It contains a strange table with the names and dates of astronomers who established, purportedly by observation, the position of the solar apogee and the obliquity of the ecliptic. One of them is Ghiyām ibn Rujjār in 1178, who can be identified as William II (who reigned in Sicily between 1166 and 1189), the son of William I and grandson of Roger II. William II is undoubtedly the patron of the unnamed Jewish astronomer mentioned by Ibn Khaldūn. Another of the "observers" is Ibn Isḥāq himself, and the date given is 1193. The date 1222 mentioned in one manuscript of Ibn al-Bannāʾs *Minhāj* is confirmed by internal evidence.

Ibn Isḥāq seems to have left only one set of numerical tables (nos. 6–58 of the Hyderabad manuscript) for the computation of planetary longitudes, eclipses, equation of time, parallax and, probably, solar and lunar velocity. These tables were not accompanied by an elaborate collection of canons, although they contained instructions of some kind for the use of a few tables. His *zīj*, therefore, was unfinished and not ready to be used. This is why the anonymous compiler of the Hyderabad manuscript tried to finish this work and to "edit" Ibn Isḥāq's *zīj* by adding both canons and

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77 On Ibn al-Zarqālluh see the most recent study by Julio Samsó in *Encyclopedia of Islam Three*.

numerical tables. The whole constitutes an impressive collection of materials in which the predominant influence is clearly Andalusī, but we do not know yet to what extent Ibn Isḥāq's contributions are original.

This unknown Tunisian compiler was not the only "editor" of the tables of Ibn Isḥāq. Two other contemporaries prepared "editions" of the same work. One of them was Ibn al-Bannāʾ who wrote his *Minhāj* with the same purpose. The other was Muḥammad ibn al-Raqqām of Tunis and Granada, who is the author of three different versions of Ibn Isḥāq's *zīj* (see below). The *zīj*es derived from Ibn Isḥāq were used in the Maghrib until the 19th century, for they allowed the computation of sidereal longitudes that were used by astrologers.

For our present purposes it suffices to mention that Ibn Isḥāq used 36°40′ for the latitude of Tunis.

Tunisian works on astronomical timekeeping

The parameter which concerns us was also used in the extensive corpus tables for astronomical timekeeping by the sun and regulating the times of prayer that were compiled in Tunis in the early 15th century. This anonymous work is entitled عمدة النظار في مواقيت الليل والنهار , *ʿUmdat al-nuẓẓār fī mawāqīt al-layl wa-ʿl-nahār*, "The pillar of those who look at the times of night and day", and it was dedicated to the Hafṣid ruler of Ifrīqiya Abū Fāris al-Mutawakkil (reg. 1394-1434), under whose dominion the capital Tunis flourished anew for a while.[78] It is these tables for timekeeping that are most revealing on latitude values.

In an anonymous Tunisian recension datable 1401 of the 'minor' universal auxiliary tables for timekeeping by the sun prepared by the Damascus astronomer Shams al-Dīn al-Khalīlī (*ca*. 1360) we witness an attempt to make the tables universal for latitudes in Ifrīqiya (corresponds to modern

78 These tables are extant in an apparently unique manuscript in Berlin (DSB Wetzstein 1150 = Ahlward 5724). See King, "History of astronomy in medieval Maghrib", pp. 180-184 and 189; and *idem*, *Synchrony*, II: 427-431 "Maghribi tables for timekeeping".

Tunisia), the Maghrib and perhaps Sicily.[79] Whereas al-Khalīlī had added to his tables for each degree of latitude from 1° to 48° (the middle of the 5th climate) a table for latitude 33°30′ serving Damascus, the anonymous Tunisian astronomer has added a set of tables for latitudes:

30°30′, 31°30′, 32°30′, 33°30′, **33°40′**, 34°30′, 35°30′, 36°30′, **36°40′**, **37°10′**, **37°30′**, **38°30′**, 39°30′.

This obviously represents an attempt to provide tables for each half-degree, and certain values are attested medieval values for specific cities: 33°40′ for Fez, 36°40′ for Tunis, 37°10′ for an unspecified location nearby, 37°30′ for 'Sicily', and 38°30′ for Qurṭuba (Córdoba).[80]

Sundials from Tunis

The Andalusī astronomer Ibn al-Raqqām, b. *ca*. 1250 in Murcia, d. 1315 in Granada,[81] lived for some time in Tunis and compiled there an astronomical handbook with tables entitled الزيج الشامل , *al-Zīj al-Shāmil*, using the distinctive value 36°37′ for the latitude of the city. At some time, problably in al-Andalus, he composed رسالة في علم الظلال , *Risāla fī 'Ilm al-ẓilāl*, *Treatise on the theory of shadows*, dealing with horizontal, vertical and inclined sundials, which may have been the medium by which sundials were introduced in Tunis, even though similar treatises had been compiled in Baghdad in the 9th century. This is a theoretical work, rich in geometrical constructions but unfortunately lacking the tables of coordinates for constructing sundials for particular latitudes generally found in Islamic treatises on gnomonics. Such tables would have enabled us to localize the treatise geographically.

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79 # On al-Khalīlī see my articles in *DSB* and *BEA* and n. 97 below. On these 'minor' auxiliary tables, not to be confused with his main universal auxiliary tables extant in MS Dublin Chester Beatty 4091, see King, *In Synchrony with the Heavens*, II: 366-371. On the Tunisian recension, extant in MS Cairo DM 689, see *ibid*., II: 395-396 and 431.

80 For such investigations Kennedy & Kennedy, *Islamic Geographical Coordinates* (1987) is indispensable.

81 On Ibn al-Raqqām see the article by Josep Casulleras in *BEA*. His treatise is published in Carandell, Risāla fī 'ilm al-ẓilāl *de Ibn al-Raqqām al-Andalusī: edicion, traducción y comentario* (1988).

All known sundials from al-Andalus exist only in fragmentary form, and all have been published.[82] Some 100 known sundials in Tunisia have recently been surveyed in a splendid new book by Fathi Jarray entitled *Mesurer le temps en Tunisie à travers l'histoire*, and I am pleased to acknowledge his assistance on the 99 which I did not already know.

An instrument of outstanding historical importance from that milieu is a marble sundial signed by Abu 'l-Qāsim ibn Ḥasan al-Shaddād and dated 746 H (1345/46).[83] This elegantly finished sundial, preserved in the Musée National at Carthage, constructed on a square marble slab of side 24.5 cm, serves specifically the times of prayer and of religious significance: the ضحا , *ḍuḥà* prayer near mid-morning; the تأهيب , *ta'hīb*, a time of preparation for the Friday sermon, one equinoctial hour before astronomical midday; the ظهر , *ẓuhr* prayer just after midday; and the عصر , *ʿaṣr* prayer near mid-afternoon. It was the markings on this precious sundial that provided the first part of the answer to the vexing question why the times of the daylight prayers in Islam are defined in terms of shadow-increases over the midday minimum.[84] (The question was vexing because these definitions occur neither in the *Qur'ān* nor in the Prophetic traditions known as the *ḥadīth*.)

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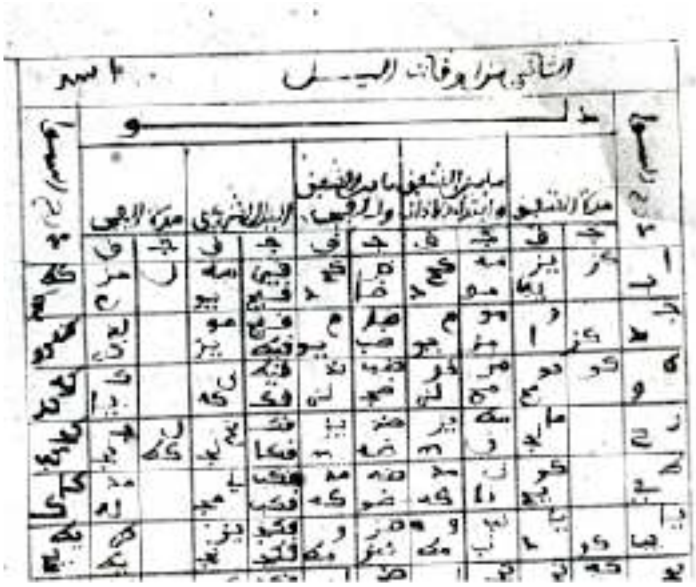
82 On these see King, "Three sundials from al-Andalus" (1978); Labarta & Barceló, "Ocho relojes de sol hispanomusulmanes" (1988); *eadem,* "Un nuevo fragmento de reloj de sol andalusí" 1995); King, "Los cuadrantes solares andalusíes" (1992).

83 On this see King, "14th-century Tunisian sundial" (1977), also my article "*Mizwala* [= sundial]" in *Encyclopaedia of Islam*, 2nd edn., and also the next note for the significance of the markings. The Carthage sundial is described anew in Jarray, *Mesurer le temps en Tunisie à travers l'histoire*, pp. 30-31.

This instrument has not been taken seriously by any historians of astronomy because it "only" shows the times of prayer; it is barely locatable on the internet. Nevertheless, it not only served to solve the mystery of the definitions of the times of daylight prayers in terms of shadow-increases, but also inspired the first attempt to write the history of astronomy in Tunis: see pp. 192-193 of my paper on the Tunisian sundial (written after the analysis of the Berlin manuscript of the corpus of tables for astronomical timekeeping for Tunis but before the discovery of the *Zīj* of Ibn Isḥāq).

84 The topic is pursued, using the Tunisian sundial and other historical evidence, in King, *In Synchrony with the Heavens*, IV "On the times of Muslim prayer": 529-622, esp. 571-573.



An extract from the anonymous Tunisian tables for regulating the prayer-times in MS Berlin Ahlwardt 5724. Values of the following functions are tabulated here in equatorial degrees and minutes for each degree of solar longitude in Leo 1°-12°: (1) the duration of evening twilight; (2) the time between nightfall and the beginning of the call to prayer; (3) the time between nightfall and daybreak; (4) the length of legal darkness; and (5) the duration of morning twilight.

The Carthage sundial from 1346, unique of its kind. The markings show only the times of institutionalized prayers from left to right: (1) the *ḍuḥà* around mid-morning; (2) the *ta'hīb* one equal hour before midday; (3) the *ẓuhr* sometime after midday; and (4) the *ʿaṣr* around mid-afternoon. A wealth of historical information can be derived from the definitions behind these markings. [Photo courtesy Alain Brieux.}

Fathi Jarray has drawn attention to two horizontal sundials in Kairouan which could be even earlier than the sundial of al-Shaddād for Tunis.[85] In addition, one of these is virtually intact. The first shows the seasonal hour-lines 2 to 10 and the curves for the *ẓuhr* and *ʿaṣr* (but not the *ta'hīb* or *ḍuḥā*), as well as an indicator of the *qibla*. No maker's name is present. The sundial, which measures 1m x 0.5m, is of precisely the same kind as the earlier Andalusī sundials, which are, however, of the same kind as those documented in books on sundial construction from 9th-century Baghdad. The second is fragmentary and shows some hour-lines and part of an inscription: ... عمل ابي بكر بن عبد , *ʿamal Abī Bakr ibn ʿAbd ...* , "made by Abū Bakr ibn ʿAbd ... ". No markings of religious significance remain. Both sundials bear an indication that they were endowed (حـــبس , *ḥabs*) to particular mosques, the second one to the Zaytūna Mosque.

Astrolabes from Tunis

We know that astrolabes were made in Tunis starting in the 10th century.[86] Listed here are six astrolabes featuring the distinctive latitude 36°40′ and pre-dating *ca*. 1500, all of which the author has catalogued:[87]

a) An astrolabe by al-Khamā'irī of Seville, the most prolific astrolabist in Andalusī history, datable *ca*. 1215. This is preserved in the Adler Planetarium and Astronomy Museum in Chicago and is not relevant to our study save that it provides the earliest attestation on an instrument of the latitude 36°40′ but with no associated locality.[88] Tunis is not mentioned on the relevant plate not least because on Andalusī astrolabes it was often misplaced at latitude 33°, as in the earliest Islamic geographical tables, which probably arose from putting it at the border between the 3rd and 4th climates.[89]

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85 Jarray, "Deux mizwala-s de Kairouan" (2009/2013), and *idem*, *Mesurer le temps en Tunisie à travers l'histoire* (2015), pp. 28-29 (fragment) and 32-33 (complete).

86 King, "Astronomy in medieval Maghrib".

87 For preliminary descriptions see King, *Catalogue of medieval Islamic astronomical instruments*, nos. (a) 1.6.2m, (b) 1.6.16p, (c) 1.6.8, (d-e) 1.6.9a-b, (f) 1.6.15e.

88 Pingree, *Eastern astrolabes in Chicago*, pp. 2-5 (no. 1).

89 Kennedy & Kennedy, *Islamic geographical coordinates*, p. 362.

b) An unsigned, undated Maghribī astrolabe preserved in the Società Ligure di Storia Patria in Genoa. It can be dated to *ca*. 1400 (Regulus is at Leo 22°). The relevant plate has **both the latitude 36°40′ and the named locality Tunis**. This instrument was published in 1878 by Pier Costantino Remondini, but he was mainly interested in the stars represented on it.[90] The 1991 Frankfurt reprint omits his excellent lithograph illustrations, but fortunately Gunther reproduced his image of the rete. This author inspected the piece in 1990 and wrote a description. The engraving is not dissimilar to that on the Tunis spherical astrolabe, but Maghribī *kūfī* tends to vary little over the centuries and any differences are due mainly to the quality of the engraving and the competence of the engraver. It would be a good idea to have another look at this astrolabe.

c) A Maghribī astrolabe signed by Ḥusayn ibn ʿAlī in 709 H (1309/10) which is preserved in the Whipple Museum of History of Science in Cambridge. This has a plate for latitude 36°40′ without mention of Tunis. The piece has a replacement rete and its most important feature is an additional universal plate by the mid-14th-century Damascus astronomer al-Mizzī.[91]

d-e) In passing we mention two instruments by ʿAlī ibn Ibrāhīm al-Jazzār, muezzin at Taza in modern-day Morocco in the middle of the first half of the 14th century.[92] The first, made in 724 H (1324) and preserved in the Musée d'Histoire des sciences at Geneva, is a solitary mater with replacement rete and plates of Indian origin.[93] The second, made in 728 H

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90 Remondini, "Astrolobio arabico di Genova"; Gunther, *Astrolabes of the World*, I, pp. 298-299 (no. 151); King, *Catalogue*, no. 1.6.16p.

91 On al-Mizzī see the article by François Charette in *BEA*. On this astrolabe and plate see King, *In Synchrony with the Heavens*, XIVb: 704-705, and *idem*, "Remarkable Italian astrolabe", pp. 37 and fig. 7 (wrong instrument), and pp. 560-561 and fig. 6 on p. 559 in the new version.

The instrument is described in an unprofessional manner in "An Islamic astrolabe", at www.sites.hps.cam.ac.uk/starry/isaslabe.html. Almost every sentence in this description is in error, and the universal plate and the replacement rete and the universal plate with its substantial inscription by al-Mizzī is not mentioned.

92 See King, *Catalogue of medieval Islamic astronomical instruments*, nos. 6.9a-b. On the latter piece, with its myrtle rete, see *idem*, "Remarkable Italian astrolabe", p. 37.

93 On this instrument see the detailed description in Archinard, *Astrolabe*.

(1327/28) and preserved in the Museum of History of Science at Oxford, has a single universal projection in the mater and a 'myrtle' (آســـي , *āsī*) shaped ecliptic on the rete.[94] This very important astrolabe merits a serious publication. It has been suggested that the engraving on these two astrolabes is the same as that on the Tunisian spherical astrolabe, to which the author cannot agree. Further, neither of those two astrolabes can be related to Tunis.

f) The Maghribī astrolabe from Imola now in Bologna's Museo della Specola is not as early as some investigators have thought, nor is it Andalusī. It is unsigned and undated, and it is incomplete, none of which is to its advantage.[95] Only one out of eight sets of latitude-dependent markings can be associated with al-Andalus, then there are two replacement plates for latitudes:

34°30´ – 35°30´ – 36°40´ – 38°30´ ,

which Marcel Destombes, the leading specialist in France on medieval instruments, tentatively associated with:

Fez – Tétouan – Málaga – Córdoba .

Since Destombes' time, and thanks to the labours of Ted and Mary Helen Kennedy in data-processing all coordinates found in medieval Islamic geographical tables,[96] we can now assert, for example, that 34°30´ is not attested for Fez (accurately 34°05´) in any known medieval source, and 36°40´ is attested for Málaga (accurately 36°43´) only in one late-16th-century Indian source. So we probably have a hidden reference to Tunis here, but the engraving is nowhere featured in the literature and is not that of the mater anyway. In brief when interpreting medieval geographical coordinates one should keep in mind that modern values are not necessarily relevant, and that data from other instruments from the same milieu as well as the Kennedys' lists will invariably prove to be more useful.

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94 *Oxford MHS astrolabe catalogue*, no. 50853 at www.mhs.ox.ac.uk/collections/.

95 Destombes, "Sur l'astrolabe d'Imola" (after da Schio, 1886); King, *Catalogue*, 1.6.15e; Hernández Pérez, *Astrolabios en la España medieval*, pp. 439-446 (thesis); also http://museospecola.difa.unibo.it/italiano/ast_01.html (accessed 2018).

96 Kennedy & Kennedy, *Islamic geographical sources*, lists arranged by place-names, source, longitudes, and latitudes.

In conclusion, I am of the opinion that the spherical astrolabe from Tunis is not to be dated later than the 15th century because it is obviously a serious astronomical instrument, and astronomy in the Maghrib did not progress in the ensuing centuries, indeed it declined, so much so that the French colonialist scholars who in the 19th century first investigated the history of Maghribī astronomy did not find anything of consequence.[97] Needless to say, they could not have known that the right places to look were Hyderabad and Berlin.[98] A new catalogue of the manuscript holdings of the Aḥmadiyya Library in Tunis lists copies of some historically important items compiled between Córdoba and Ghaznà but mentions no copies of works compiled in Tunis itself.[99]

In spite of the decline of astronomy in Tunis, Maghribī craftsmen made respectable astrolabes (and quadrants and sundials) into the 19th century.[100]

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97 Delphin, "L'astronomie au Maroc" (1891), and Renaud, "Astronomie et astrologie marocaines" (1942).

98 A substantial corpus of tables for astronomical timekeeping (Tunis, 14th century) preserved in Berlin was first investigated in 1977. The monumental astronomical tables with explanatory text (*zīj*) of Ibn Isḥāq (Tunis, early 13th century), mentioned by Ibn Khaldūn (*ca*. 1375) as the major astronomical work in Tunis in his time, were discovered in Hyderabad in 1978.

99 Abdeljaouad & Hedfi, eds., *Manuscrits scientifiques du Fonds Ahmadi* (*mathématiques – astronomie – astrologie*), Tunis, 2018

100 A list of all known Maghribī astrolabes is in King, "Astronomy in the Maghrib", pp. 199-206. Many early ones are described in *idem*, *Catalogue of Islamic Astrolabes*, Section 1.6. For sundials from Tunisia see Jarray, *Mesurer le temps en Tunisie*.

4 The spherical astrolabe of Mūsà

"The importance of the planispheric astrolabe has long been recognised by historians of early scientific instruments. There is historical evidence that another type of astrolabe, the spherical astrolabe, existed alongside the planispheric astrolabe. Until a few months ago, this evidence consisted solely of manuscript descriptions of the instrument, as no spherical astrolabe was known to have survived. The present paper illustrates and describes an apparently unique example of a spherical astrolabe recently acquired by the Museum of the History of Science, University of Oxford." Francis Maddison, "15th century spherical astrolabe" (1962), pp. 101-102.

"The (Oxford spherical astrolabe) is one of the most interesting (astrolabes) I've found, a spherical astrolabe that would be almost impossible to craft with [fifteenth]-century technology, but potentially simple with Hermetic craft magic. I think a spherical astrolabe would make a great talisman concept for an astrological magus and is distinct enough from an armillary sphere to play a potential role in (Ars Magica Fifth Edition) Sagas." Jarkmand de Vries, "On astrolabes" (2013). No comment!

"The universe in your grasp. That is the promise of this spherical astrolabe, which is perfectly sized to nestle neatly in the palm of your hand. More than merely an image or a representation, it is a working device that captures and even seems to control the heavens." Silke Ackermann, *Oxford MHS Director's choice*, p. 40.

Provenance

The Museum of the History of Science at Oxford has by far the largest and richest collection of medieval scientific instruments in the world. One of its prize possessions is a brass spherical astrolabe with Arabic inscriptions which was acquired at an auction at Sotheby's of London in

1962.[101] Long before it came to Sotheby's it belonged to a lady who had at some time deposited it with Harrods of London. Upon her passing, her heirs offered it for auction at a Harrods sale, where at an unknown date it was sold for *ca*. £9 (nine sterling!). In 1962 it was put up for auction by a Mr. Charles Walter of Romford, Essex, who had acquired it at Harrods. At Sotheby's the piece sold for £3,600 (at that time $10,080) to the Oxford Museum.[102]

This exciting new acquisition was duly published in 1962 by the Museum's Curator, Francis R. Maddison, in a classic study with great attention to detail and with full command over the relevant literature.[103] His description includes a reliable list of stars represented together with their positions, although no attempt was made to analyze these positions. Unfortunately, Maddison did not determine the latitude underlying the seasonal hour markings.

Images of this iconic piece have appeared numerous times in various publications and online since the time of Maddison, all but one of which add no information on it.[104] This is a pity, because anyone who had looked seriously at the star-names and the star-positions would have seen that it is non-functional, which is a pity too. Also, the historical context of this piece had never been seriously investigated because nobody had any idea where it came from. It has been exhibited several times, including, for

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101 *Oxford MHS Astrolabe Catalogue*, no. 49687, temporarily (summer, 2018) unavailable at www.mhs.ox.ac.uk/collections/ under 49687, with many illustrations. It still appears at https://www.mhs.ox.ac.uk/collections/imu-search-page/record-details/?TitInventoryNo=49687&querytype=field&thumbnails=&irn=2113. The Sotheby's 1962 catalogue is available at www.mhs.ox.ac.uk/wp-content/themes/mhs-2017-responsive/imu-media.php?irn=55068. See also Ackermann, *Oxford MHS Director's choice*, pp. 40-41. All of the Museum's information on this piece overlooks the fact that the seasonal-hour markings are for latitude *ca*. 41°.

102 This and other useful basic information was kindly provided by Stephen Johnston of the MHS in Oxford.

103 Maddison, "A 15th-century spherical astrolabe".

104 For example, in A. I. Sabra's chapter "The exact sciences", in John R. Hayes, ed., *The Genius of Arab civilization – Source of Renaissance*, 1975, pp. 147-169, esp. p. 163; al-Hassan & Hill, *Islamic technology*, p. 68; also King, *In Synchrony with the Heavens*, I: 69. To this one might add www.alhamdlilah.com/blog/view/522/-مـــا-هـــو-الاسطرلاب .

example, at the 1976 exhibition "World of Islam Festival" at the Science Museum, London (unpublished descriptions by Francis R. Maddison and Anthony J. Turner); the 1985 exhibition "Instrumentos astronomicos en la España medieval" at Santa Cruz de Las Palmas; the 1992 exhibition "El Legado Científico Andalusí" at the Museo Arqueológico Nacional in Madrid; and the 2009 exhibition "Galileo" at the Palazzo Strozzi in Florence (excellent short description by Jim Bennett).[105]

Dimensions and weight

The instrument has a diameter of 8.3 cm and weighs 261.7 grams. The two halves of the sphere weigh distinctly different amounts, 104.4 and 57.3 grams, respectively.

The inscription

The piece bears no textual indication of its provenance other than the name 'Mūsà' and the date of construction engraved by the markings for the seasonal hours on the lower half of the sphere.[106] The inscription reads:

105 Vernet & Samsó, eds., *Instrumentos astronomicos en la España medieval*, p. 71; Maddison & Turner, *Catalogue of an Exhibition 'Science and Technology in Islam' ...* , p. 68 (unpublished); Vernet & Samsó, eds., *El Legado científico andalusí ...* , p. 220 (no. 35); and Jim Bennett in Galluzzi, ed., *Galileo*, p. 195 (IV. 3.2).

106 Since the piece became available for study only in 1962 its maker is not mentioned in Mayer, *Islamic astrolabists* (1956). The new version of this listed as Brieux & Maddison, *Répertoire*, is to appear in 2018 after a delay of some 30 years.

عمل موسى سنة ضفه , *ʿamal Mūsà sanat ḍ-f-h,*

"the work of Mūsà, in the year 885 (Hijra)", that is, 1480/81.[107]

Since the instrument is obviously not Western Islamic, that is, Maghribī, Francis Maddison reasonably labelled it "Eastern Islamic". This author has previously referred to it as "Syrian or Egyptian" but always thought this was risky because it does not bear any resemblance to any known instruments from either locality. It is certainly not Iranian, as claimed on the Museum website, nor from "somewhere in present-day Syria", as suggested by Daril Dayton.[108] It has been claimed as "Moroccan", and on the internet it even becomes "Indian".[109] As we shall show, it was made in Istanbul.

The engraving is in a balanced, fairly elegant, 'soft' Eastern *kūfī* with a few peculiarities. These 'curiosities' could be interpreted as having been engraved by someone who was not completely familiar with Arabic, but engraving on a sphere or on a fragile hemispherical rete is not for the timid.

The sphere

The sphere is hollow and its two halves can be unscrewed and dismantled at the horizontal circumference. One of these two hemispheres is considerably heavier than the other. The top half weighs 104.4 gr. It bears altitude circles for each 2° with additional silver markings for each 5° and

107 The typical Arabic inscriptions for **M**akers' names are عمل م *ʿamal **M***, 'the work of **M**', or عمله م *ʿamalahu **M***, meaning '**M** made it'; in these two cases we have the noun عمل *ʿamal* 'work' and the verb عمل *ʿamala*, 'he made'. See Mayer, *Islamic astrolabists and their works*, pp. 13-15, for a discussion. On Oxford's MUSA we have the phrase صنعه م *ṣanaʿahu Mūsà*, "**M** constructed it" or "constructed by **M**", there being little difference in meaning between the two verbs. In English we would say "Made by **M**". See Mayer, *Islamic astrolabists and their works*, p. 13, on these formulae. On European astrolabes the instrument sometimes speaks: see King, *Ciphers of the monks*, pp. 422-423, for an inscription on an instrument exchanged between two early-16th-century Humanists (**B**erselius and **A**merotius) ***B A** me dono dedit*, "**B** gave me to **A**" with a companion statue of the Virgin Mary by Daniel **M**auch inscribed ***M** fecit*, 'made by **M**' and then *sum **B***, 'I belong to **B**'.

108 Dayton, "Spherical astrolabe" (2016), inevitably without any evidence.

109 www.gettyimages.de/detail/nachrichtenfoto/the-only-complete-example-of-a-spherical-astrolabe-it-nachrichtenfoto/152196501#/ (1980).

azimuth circles for each 10°. Two altitude scales show divisions for each 5° with arguments in silver with holes for each 2°. This arrangement is reasonably well executed (when compared to the markings on the next piece we shall discuss). There are three other similar altitude scales at 90°, 180° and 270° around the circumference from this one, but without holes, to avoid excessive turning of the rete. The altitude scales end at 80° above which there is a circular 'bald spot' or small empty circle marked 90°.

The lower hemisphere weighs 57.3 gr. It is marked with a horizon scale around its rim, the upper part of which would cover the inset rim of the upper hemisphere. The rim is divided into single degrees, each 5 of which are labelled on the scale below. The *abjad*-letters corresponding to the 5° divisions are engraved forward from the west to the north and backward to the south to distinguish between the different quadrants of the horizon. The backward letters present a curious spectacle since this is a rare practice; they look rather like Coptic numerals.

On the lower hemisphere we find first of all the lower halves of the meridian and the prime vertical. Then there are three parallel arcs of circles. The small circle closer to the north is the Tropic of Cancer; the small circle further from the north is the Tropic of Capricorn. The great circle arc in the middle is the celestial equator. Its extremities are marked المشرق , *al-mashriq* and المغرب *, al-maghrib*, east and west. Arcs of small circles have been drawn between the one-twelfth divisions of the solstitial circles: these represent the seasonal hours, labelled from 1 to 12. To understand the situation for the first and twelfth hours we must imagine away the scale below the horizon so that the parallel circles could all be seen encountering the horizon.

The latitude underlying the markings for the seasonal hours

Now these markings conceal a terrestrial latitude, which can be derived by examining the intersections of the solstitial and equinoctial curves with the meridian: the co-latitude is equal to the midday altitude of the sun at the equinoxes, that is, the latitude is 90° minus the solar equinoctial midday altitude. The underlying latitude was found for the first time by Ernesto Canobbio in 2009 to be just less than 42°, perhaps 41°30´.[110] He calls this

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110 Canobbio, "Réflexion sur ... les deux astrolabes sphériques", pp. 1 and 4. The author did not zero in on Istanbul but considered the possibilities of an Ottoman, Timurid or Moghul provenance. The latitude was not discussed by Francis Maddison.

operation un "*jeu d'enfant*", but nobody young or old had played it on MUSA for almost 50 years. This result is the latitude of the 5th climate, but it also serves Istanbul.

Could this latitude of *ca*. 41° have served anywhere else in the Eastern Islamic world? It is worth mentioning that the only other known medieval centre of astronomical activity with this latitude[111] is Shirvan, in N.W. Iran, where in the 12th century the rather mysterious astronomer Farīd al-Dīn ʿAlī ibn ʿAbd al-Karīm al-Shirwānī known as al-Fahhād compiled a total of six *zīj*es (in Arabic), all lost in their original form although partially preserved in Yemeni and Byzantine *zīj*es.[112] Some of his latitude-dependent tables might have been adopted in Byzantine works simply because they would also have served Constantinople, but the Byzantine astronomer Gregory Chionades (1240-1320), who incorporated them in his work, also used 45° for Byzantium in his worked examples.[113] I have already mentioned above the city jumping from one climate to another in Byzantine astronomy. Also we shall mention below Shukrullāh Shirvānī who made an astrolabe for Sultan Bāyazīt II (with inscriptions in Persian) with a plate for the latitude of 41° about the time Mūsà made his spherical astrolabe. Further, as we shall see, contemporaneous local astronomical works used latitudes 41° or 41°15′ or 41°30′ for the latitude of Istanbul. Finally, no astrolabes or other instruments made anywhere else with latitude *ca*. 41° are known.

The rete

The upper part of the rete consists of a pierced hemispherical frame bearing the star-pointers. This has the ecliptic ring as base circumference, with a scale divided into 30° intervals for the zodiacal signs, subdivided in

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111 It is accepted values of latitudes in medieval times that are of concern here. See Kennedy & Kennedy, *Islamic geographical coordinates*, pp. 699-702, on localities with latitudes between 40° and 42° recorded in medieval astronomical and geographical sources.

112 Kennedy, "Islamic astronomical tables", p. 6, *etc*. (nos. 23, 53, 58, 62, 64, 84); King, *Astronomy in medieval Yemen*, p. 23 (*sub* al-Fārisī); *idem* & Samsó & Goldstein, "Islamic astronomical handbooks and tables", p. 45.

113 King, "Notes on Byzantine astronomy", pp. 117-118, commenting on Pingree, *Chioniades: Astronomical works*. On Gregory Chioniades see the *BEA* article by Raymond Mercier.

5° intervals, and further subdivided into single degrees. There is an equinoctial colure inclined to this and passing through the 'zenith'. Then there is a solstitial colure perpendicular to the horizon, also passing through the 'zenith'. On the colure starting from the Capricorn 0° on the ecliptic there is a double latitude scale consisting of two quadrants of scales separated by a space sufficient to receive a silver pin that can be adjusted on the scale and penetrate the appropriate hole in the sphere. The arguments on the right hand side of the double scale run from [0°] at the top - 5 - 10 - 5 - 20 - ... - 80 - 5 - [90°] at the ecliptic. On the left hand we find identical markings <u>in reverse</u>. The subdivisions into single degrees have been inserted with some abandon. Within the two sides of this scale there is a runner which can be moved almost the entire length of the scales to set the latitude when the sphere is secured inside the rete. The double latitude scale is marked in 5°-intervals labelled upward on the left and downward on the right. The subdivisions into single degrees have been inserted with some abandon. At the top there is a rider with two 'legs' and at the upper part of this is supported a shackle, to which is attached a semicircular ring.

Considerable care has been taken by the designer or maker to ensure that a maximum of symmetry controls the star-pointers. This achieves a sense of symmetry for the rete that is evident from all perspectives and is only occasionally interrupted by a small pointer here or there. The 'cost' of this is a severe limitation on the stars that can be represented under these constraints. The coordinates underlying the star-pointers were published in Francis Maddison's study. As far as the author is aware, these have not been researched since. Which, as we shall see, is a pity, because at least two of the pointers, including the one for the only bright star selected, are incorrectly positioned – see below.

A circular frame inclined to the plane of the ecliptic at about 23.5° represents a small circle parallel to the celestial equator and securely to the north of the ecliptic, that is, away from the ecliptic scale. Its lowest point corresponds to Cancer 0° = 90° on the ecliptic scale and it is joined to that scale by two small stays. Its uppermost part is attached to the latitude scale between arguments 40° and 50°. Being parallel to the celestial equator it serves to measure arcs related to the equator such as day and night arcs of heavenly bodies or hour angles and right ascensions.

The lower part of the rete consists of a frame of three arcs of circles attached to each other at a small circular button at the bottom. One of these branches is attached at longitude Virgo 0° = 150° to the ecliptic with a closed shackle and a fixed silver pin that cannot be removed. The other two are attached to the ecliptic at Taurus 0° = 30° and Capricorn 0° = 270° by means of shackles with removable silver pins.

All inscriptions on the sphere and all arguments on scales and all curves on it are overlaid with silver. The ecliptic scale on the rete, and the latitude scales up to the throne and suspensory apparatus are also overlaid with silver.

Various parts of the rete are made of silver or overlaid in silver, for example, the ecliptic scale, the auxiliary equatorial scale, both sides of the latitude scale, but no star-pointers.

There is no means on MUSA for measuring celestial altitudes. Further study of the available treatises, especially those of Ḥabash and al-Wāsiṭī, will be necessary to see what was envisaged by their authors in this regard. Perhaps something like the clumsy pair of diametrically-opposed parallel tangential rules with sights that are connected to each other by a semi-circular strip of metal such as is proposed in the Alfonsine treatise?[114] Already in the early 11th century al-Bīrūnī had mentioned a conical sighting-tube fitted along the length of an astrolabe alidade; such a device is found on an astrolabe made by the Yemeni Sultan al-Ashraf in 1295, now in the Metropolitan Museum of Art in New York City.[115]

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114 Seemann & Mittelberger, "Das kugelförmige Astrolab", pp. 10-11. A similarly precarious (and inappropriate) arrangement for an alidade is found on the compendium (multi-functional instrument) of the 14th-century Damascus astronomer Ibn al-Shāṭir – see Janin & King, "Ibn al-Shāṭir's compendium", pp. 204-206 and 209-213.

115 See King, *In Synchrony with the Heavens*, XIVa "An astrolabe made by the Yemeni Sultan al-Ashraf", pp. 615-657, esp. pp. 631-632, fig. 2.4, and 636, figs. 3.3 and 3.4.

5 The selection of stars on MUSA

> " ... prime importance must always be given to a star's name. When this appears to be in the wrong position, there is also a strong likelihood that other things on the astrolabe ... may be wrong." Paul Kunitzsch, "The stars on the astrolabe" (2005), p. 46, writing about astrolabes in general.

> "This project for the first time presents ancient Arab astronomical traditions within their own cultural contexts instead of fragmented within the confines of Greek-oriented modern astronomy." Danielle Adams, "Two Deserts – One Sky – Arab star calendars", available at onesky.arizona.edu (accessed 2018).

Stars on medieval globes and astrolabes

The Arabs before Islam had their own complex star-lore of identification of stars, star-groups, and lunar mansions.[116] When the monumental star-catalogue of Ptolemy of Alexandria (137 C.E.)[117] became available to the Muslims in al-ʿIrāq they added colour to it in their translations and editions by inserting many of their own concepts, including their names of star-groups (e.g., الدجاجة , "the chicken (or bird)" for Cygnus, "the swan"), and appellations relating to the 28 lunar mansions.

The stars on Islamic celestial globes are, not surprisingly, arranged by constellations. Usually these constellations will be illustrated, so that groups of stars in a given constellation will be represented thereabouts (and nowhere else). The stars featured on this spherical astrolabe are of

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116 This is documented in Kunitzsch, *Sternnomenklatur der Araber*. See also the article "Ibn Qutayba" by Kunitzsch in *DSB*, not included in *BEA* (!) because most historians of astronomy are not interested in folk astronomy; indeed, some have never heard of it. For an overview see Varisco, "Islamic folk astronomy", and various articles by Daniel Varisco and Petra Schmidl in Ruggles, ed., *Handbook of archaeoastronomy and ethnoastronomy.* A new website featuring aspects of Arab star-lore in a visual and reader-friendly fashion, at the same time respecting the original Arabic star-names, is Danielle Adams, "Two Deserts – One Sky – Arab star calendars" available at onesky.arizona.edu (accessed 2018).

It is appropriate to include a mention of Arab navigation here, if only to recommend the reader to the most reliable study, namely, Tibbetts, *Arab navigation* (1971).

117 The basic source is Kunitzsch, *Der Sternkatalog des Almagest – Die arabischmittelalterliche Tradition*.

this variety, but only loosely because only one or two stars can be featured from a limited number of constellations. Sometimes up to 1,000 stars can be marked on Islamic globes. Emily Savage-Smith has provided a most useful illustrated overview of such constellations, covering the Greek images and the indigenous Arab names for the stars in them. It is these designations that can help us see what is going on with the stars on the two spherical astrolabes. Unlike much of the available literature, this account is readily available and eminently readable.[118]

On most medieval astrolabes, on the other hand, the stars were selected (a) by tradition, historical, local or dynastic; (b) by brightness, inevitably, the brighter the better; or (c) by symmetry, in particular with respect to the vertical diameter; or (d) all of the above. The retes of the earliest Islamic astrolabes had a series of stars inherited from Greek sources on the astrolabe. But this soon changed and already in the spectacular astrolabe of al-Khujandī dated 984/85 we find a wider selection of stars and even a symbolic, illustrated lunar mansion.[119] Shortly thereafter al-Ṣūfī compiled a list of astrolabe-stars, but this actually bears little relation to the selections of stars that were used on later Islamic astrolabes.[120] It is also worth mentioning that the star-pointers on Islamic astrolabes are usually clearly marked with an unambiguous star-name. On many of the earliest medieval European astrolabes, say, from the 10th to the 14th century, the stars are often confused.[121] All that one actually needs in practice is one or two bright stars in each quadrant; the rest are essentially for decoration.[122]

Now the 20 or so stars on MUSA include about one-third to one-half of the standard astrolabe stars, which number some 30 stars. Paul Kunitzsch in 1959 published a full list of some 60 'astrolabe stars' but these were

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118 Savage-Smith, *Islamicate celestial globes*, pp. 114-212, and Paul Kunitzsch's corrections in his review.

119 Detailed description in King, *In Synchrony with the Heavens*, XIIIc: 503-517, esp. pp. 511-512.

120 Kunitzsch, "The stars on the astrolabe".

121 King, "The stars-names on three 14th-century astrolabes from Spain, France and Italy".

122 An arrangement with just four stars is found on the rete of one remarkable Italian astrolabe from *ca*. 1300 based on an Islamic prototype: see King, *Synchrony*, XIIId: 565-567.

identified from often wretched medieval European star-lists, not from medieval Islamic astrolabes.[123] The same author in 1990 published a study of the 55 astrolabe stars listed by ʿAbd al-Raḥmān al-Ṣūfī (Shiraz, *ca*. 1000), the leading Muslim scholar on the constellations and the stars.[124]

Whilst we expect to encounter some of these stars on the spherical astrolabe, we have to impose on this already restricted selection of stars two conditions. First, as noted above, the stars must be north of the ecliptic (since we are dealing here with a northern spherical astrolabe). Second, the stars should be strictly symmetrically distributed on the rete of a spherical astrolabe. This process explains why on MUSA we have what at first sight is a very strange selection of stars, including some very insignificant ones that are not part of any standard set.

On the vast majority of medieval Islamic astrolabes the star-pointers are properly marked and generally in the appropriate positions. This is not the case with medieval European astrolabes, where the star-names and positions may be problematic. Even on carefully made astrolabes an error can creep in. For example, one of the star pointers on the sole surviving Byzantine astrolabe from 1062 is labelled for the wrong star.[125] We should keep this in mind as we investigate MUSA.

The Alfonsine star-table for spherical astrolabes

The only available list of stars found in any surviving treatise on the spherical astrolabe is in the Alfonsine treatise. The positions of some 14 stars were carefully computed in Toledo for an epoch *ca*. 1250 using the out-dated star-table of al-Battānī (Raqqa, *ca*. 900), possibly the only one available there at the time.[126]

When the author started the present venture he hoped that this table might be of prime assistance in an endeavour to better understand the Oxford spherical astrolabe. This he soon realized that this was wishful thinking. The table is, nevertheless, of considerable importance for our study, if only

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123 Kunitzsch, *Arabische Sternnamen in Europa*, pp. 59-96. However, the stars found on astrolabes present different picture: see King, "Stars-names on three 14th-century astrolabes from Spain, France and Italy".

124 Kunitzsch, "Al-Ṣūfī and the astrolabe stars".

125 King, *Astrolabes and angels*, pp. 226-227.

126 Samsó, "Spherical astrolabe".

from an inspirational point of view, so it is reproduced here in its essence in two manifestations. I have suppressed the Castillian names of the stars and kept only the Arabic names and their equivalents. In the first table the entries are in the same arbitrary order as in the original. In the second, I have arranged the list in order of increasing (tropical) longitude.

The Alfonsine table of stars for marking on spherical astrolabes in the original order

(names here arranged to be easily understood; longitudes are tropical)

	Arabic name	**Transliteration**	**Identification**	**Longitude / Latitude**
1	رأس الحية	*ra's al-ḥayya*	γ Draconis Eltanin	256° / 26°
2	السماك الرامح	*al-simāk al-rāmiḥ*	α Boötis Arcturus	194 / 32
3	الفكة	*al-fakka*	α Coronae B Alphecca	211 / 45
4	النسر الواقع	*al-nasr al-wāqiʿ*	α Lyrae Vega	274 / 62
5	الردف	*al-ridf*	α Cygni Deneb	326 / 60
6	رأس الغول	*ra's al-ghūl*	β Persei Algol	046 / 23
7	العيوق	*al-ʿayyūq*	α Aurigae Capella	072 / 23
8	النسر الطائر	*al-nasr al-ṭā'ir*	α Aquilae Altair	290 / 29
9	رأس المسلسلة	*ra's (al-mar'a) al-musalsala*	α Andromedae = δ Pegasi Alpheratz	004 / 26
10	جناح الفرس	*janāḥ al-faras*	γ Pegasi Algenib	359 / 13
11	الدبران	*al-dabarān*	α Tauri Aldebaran	059 / 05
12	مقدم الذراعين	*muqaddam al-dhirāʿayn*	α Geminorum Castor	100 / 10
13	قلب الاسد	*qalb al-asad*	α Leonis Regulus	139 / 00
14	الصرفة	*al-ṣarfa*	β Leonis Denebola	161 / 12

The Alfonsine table of stars for marking on spherical astrolabes with entries rearranged according to increasing longitude

(names here arranged to be easily understood; longitudes are tropical)

No.	Arabic name	Transliteration	Identification	Longitude / Latitude
1	رأس المسلسلة	*ra's (al-mar'a) al-musalsala*	α Andromedae δ Pegasi Alpheratz	004° / 26°
2	رأس الغول	*ra's al-ghūl*	β Persei Algol	046 / 23
3	الدبران	*al-dabarān*	α Tauri Aldebaran	059 / 05
4	العيوق	*al-ʿayyūq*	α Aurigae Capella	072 / 23
5	مقدم الذراعين	*muqaddam al-dhirāʿayn*	α Geminorum Castor	100 / 10
6	قلب الاسد	*qalb al-asad*	α Leonis Regulus	139 / 00
7	الصرفة	*al-ṣarfa*	β Leonis Denebola	161 / 12
8	السماك الرامح	*al-simāk al-rāmiḥ*	α Boötis Arcturus	194 / 32
9	الفكة	*al-fakka*	α Coronae B Alphecca	211 / 45
10	رأس الحية	*ra's al-ḥayya*	γ Draconis Eltanin	256 / 26
11	النسر الواقع	*al-nasr al-wāqiʿ*	α Lyrae Vega	274 / 62
12	النسر الطائر	*al-nasr al-ṭā'ir*	α Aquilae Altair	290 / 29
13	الردف	*al-ridf*	α Cygni Deneb	326 / 60
14	جناح الفرس	*janāḥ al-faras*	γ Pegasi Algenib	359 / 13

These 14 stars are, without exception, a subgroup of the stars used on Islamic astrolabes, although three (nos. 5, 7 and 14 in the second list above) were less commonly used than the others. They all have the double advantage of being bright stars and presenting a reasonably symmetrical arrangement on a standard astrolabe rete.

As will become apparent, it seems unlikely that Mūsà would / could have compiled such a star-table himself. The errors in his work indicate that this was not his forte.

Considerations of symmetry and space available for inscriptions

On a spherical astrolabe of diameter *ca*. 10-15 cm, it is reasonable to mark some 20 stars, although half of that would suffice. However, as on a standard astrolabe rete, the pointers should not be too long, otherwise they might become bent. They also need to be arranged on the rete in such a way that the pointers are not all based on the ecliptic ring or the four vertical stays. At some stage, some astronomer with a sense of artistic style developed the idea of a set of arcs attached symmetrically to these basic components. The result was aesthetically pleasing but left little room for the star-names.

On northern spherical astrolabes in general, as we know from the texts, and of course on MUSA too, only stars to the north of the ecliptic can be represented. In other words, only stars of the family that we normally find within the ecliptic circle on a standard astrolabe can be expected. These are mainly not selected because of their brightness, nor because of their positions, but because of their positions relative to each other. A criterion for inclusion in the list is their position relative to the principal diameters of the rete and ecliptic ring. Symmetry is a prime concern.

At some time, somebody proposed engraving abbreviations of the Arabic versions of Ptolemy's designations, such as مـــنكب , *mankib*, "shoulder", instead of the full المنكب الايمن من العواء , *al-mankib al-ayman min al-ʿuwāʾ*, "the right shoulder of Boötes" (δ Boötis). When first confronted with these star-pointers one may be totally confused by all the "heads", "necks", "shoulders", "shin-bones", and "tails", without any indication to whom or what they belong, and which side of whatever body, right or left.

Procedure to be adopted in the analysis

We present the names of the stars as given on MUSA. There are no points (dots) on the letters of the star-names, and, as is usual in medieval Arabic, no vowels whatsoever. Being unable to write Arabic without dots with the software available to me I give the maker benefit of the doubt where appropriate. Thus, for example, I render a certain cluster of unpointed letters as قفزة , *qafza*, "jump", rather than فقرة , *fiqra*, "vertebra". Both words are identical when written without points (dots).

Coordinates are then given for each pointer. Francis Maddison, when investigating the star-positions on MUSA, had the good fortune of having a set of altitude circles available on the instrument.[127] He wrote:

> "For the longitudes this involved an estimation by eye (with an increasing probability of inaccuracy the higher the latitude of the star) as the azimuths are engraved at intervals of 10°."

The latitudes he could estimate from the altitude circle underneath the end of the pointer.

The positions on MUSA recorded by Francis Maddison need to be checked again. Apparently nobody has checked the coordinates on MUSA since his time.

The principal star-catalogue available in the Eastern Islamic world in the 15th century

There are few original, serious Arabic treatises on the spherical astrolabe and only the Alfonsine one is known to have a list of star-positions. Now Muslim astronomers compiled numerous tables of star-positions over the centuries.[128] Positions might be given in ecliptic coordinates – longitudes, which increase (on account of the precession of the equinoxes) by about 1°

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127 Maddison, "15th-century spherical astrolabe", p. 107, n. 19.

128 King & Samsó & Goldstein, "Islamic astronomical handbooks and tables", pp. 27-28. For a brilliant investigation of the earliest star-tables (early 9th century) of the Muslim astronomers see Mozaffari, "Star tables in the *Mumtaḥan Zīj*".

in about 70 years,[129] and fixed latitudes (since the stars move parallel to the ecliptic). Or they might be given in equatorial coordinates – ascensions and declinations – both of which change slowly with time; these are more useful than ecliptic coordinates for the purpose of astronomical timekeeping. Some tables might show ecliptic coordinates from some reliable earlier source adjusted for precession and then converted to equatorial coordinates by means of a non-trivial trigonometric formula. Or the first coordinate, more useful for the construction of standard astrolabes, might be the mediation, the ecliptic longitude that culminates with the star. In particular, the popular treatise on the planispheric astrolabe by the 9th-century Baghdad astronomer al-Farghānī had a star-table for 25 stars with both ecliptic and equatorial coordinates.[130]

For our present purposes, we turn to the list of close to 1,000 stars and their longitudes and latitudes in the Persian زيـــج ســـلطانـــي , *Zīj-i Sulṭānī*, Arabic الـــزيـــج الســـلطانـــي , *al-Zīj al-Sulṭānī*, the monumental astronomical handbook with tables and explanatory text prepared by the Sultan Ulugh Beg and his astronomers at Samarqand *ca*. 1437.[131] This was the most substantial star-table in pre-modern times together with those of Ptolemy (Alexandria, *ca*. 137), al-Ṣūfī (Shiraz, *ca*. 1000), and Tycho Brahe (Denmark, *ca*. 1575). This work of Ulugh Beg became known in Syria and Turkey within a few decades of its completion, and Arabic and Turkish versions were prepared. It was certainly available in Istanbul because the

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129 The 'easiest' star to deal with in astronomical tables and instruments, namely, Regulus, is so close to the ecliptic that its position can be used to date most medieval instruments featuring stars. The celebrated Egyptian astronomer Ibn Yūnus (on whom see the articles in *DSB* and *BEA*) measured its position as close to Leo 16° = 136° in the year 1003. His excellent value of precession was 1° in $70^{1}/_{4}$ Persian years of 365 days. Regulus appears on ZAIM, but all is not well ... .

130 See Lorch, *Al-Farghānī on the astrolabe*, pp. 125-128. A detailed analysis of the earliest tables from early-9th-century Baghdad, on which al-Farghānī based his values, is in Mozaffari, "Star tables in the *Mumtaḥan Zīj*".

131 # On Ulugh Beg see the articles in *DSB* by T. N. Kara-Niiazov and in *BEA* by Benno van Dalen. On his *zīj* see also Kennedy, "A Survey of Islamic astronomical tables", pp. 125–126 and 166–167, and King & Samsó & Goldstein, "Islamic astronomical handbooks and tables", pp. 53-54. See also n. 124 above. Various studies by Kevin Krisciunas, including "The Legacy of Ulugh Beg" and "The accuracy of the measurements in Ulugh Beg's star catalogue" (both 1992) and more, deal with the European editions and the accuracy of the tables.

prominent astronomer and polymath ʿAlī Qūshjī arrived there in 1472 indirectly from the Observatory at Samarqand, where he had assisted in the observations under Ulugh Beg.[132] The work later attracted the attention of Orientalists at Oxford: Thomas Hyde published it there in 1665.

Ulugh Beg's star catalogue (hereafter **UB**), was published by the English amateur astronomer Edward Knobel in 1917,[133] with emphasis on the stars and their positions rather than on their Persian names, although these, already published by Hyde, are treated in an appendix.

Since we can date MUSA to the late 15th century, it seems reasonable to suppose, at least as a starting hypothesis, that the stars on them were positioned from a list derived from Ulugh Beg's catalogue, in which the coordinates are given with remarkable accuracy. Given the size of the instruments and the impossibility of measuring the positions of the pointers to within say ±1° or ±2°, we need not take into consideration the precessional increase in longitude of *ca*. $^1/_2$° over one-half of a century since the time of Ulugh Beg.

The positions of the star-pointers on MUSA

> "These names are not always the full name of the star and in some cases exact identification of the star (or stars) is difficult."
> Francis Maddison, "A 15th century Islamic spherical astrolabe" (1962), p. 107, n. 19.

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132 # See n. 139 above.

133 Knobel, *Ulugh Beg's Catalogue of Stars*.

We first list the 19 stars on MUSA and their ecliptic coordinates as published by Francis Maddison in 1962.[134] He explained that for the longitudes this involved an estimation by eye (with an increasing probability of inaccuracy the higher the latitude of the star) as the azimuths are engraved at intervals of 10°. The latitudes could be read off from the appropriate altitude circle. I think it would be wishful thinking to suppose that Maddison's values were all accurate to the nearest degree. Only when someone measures them again shall we find out. It must be noted that several of the star-names on the pointers are not immediately recognizable star-names. Maddison rather wisely refrained from trying to identify the stars from their Arabic names.

The present author has not measured the star-positions himself. The staff of the Museum of History of Science at Oxford had no inkling that anybody had worked on the stars on MUSA since the time of Francis Maddison. Nor had the author until September 3, 2018, when Ernesto Canobbio sent him Paul Kunitzsch's interpretation from 2009. On July 2, 2018, I had spent a day with Paul Kunitzsch in Munich and he was no longer aware that he had worked on Maddison's data.

The indirect assistance of Prof. Paul Kunitzsch in the present undertaking is gratefully acknowledged; we have used his identifications of the stars on MUSA in the letter of April 14, 2009, graciously communicated to us by

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134 Maddison, "15th-century Islamic spherical astrolabe", p. 107, n. 19 (format slightly altered):

"The star-names, as inscribed on the (rete), are listed below. I have added the ecliptical coordinates of each star (all values of β [latitude] are, of course, positive), determined by the almucantars [altitude circles] and azimuths, engraved on the globe. For the longitudes this involved an estimation by eye (with an increasing probability of inaccuracy the higher the latitude of the star) as the azimuths are engraved at intervals of 10°; it must be remembered that some of the star-pointers have been slightly bent since the instrument was made: 1) *sirra* [*leg. surra*] λ 9° / β 36°; 2) *khaḍīb* 28° / 55°; 3) *muthallath* 34° / 16°; 4) *miʿṣam* 48° / 41.5°; 5) *rukba al-y[u]mnà* 61° / 34°; 6) *fawq al-rukba* 120° / 37°; 7) *al-naʿsh* 140° / 45°; 8) *fiqrat* [*leg.*: *qafzat*] *al-ūlà* 153° / 27°; 9) *sāqā* [probably to be read *sāq* although the pointer is marked *sāqā*!] 193° / 24°; 10) *mankib* 208° / 50°; 11) *fakka* 218° / 45°; 12) *al-rāmiḥ* 230° / 32°; 13) *janb* 236° / 15°; 14) *al-rāʿī* 257° / 35°; 15) *dhanab* 283° / 36°; 16) *minqār* 300° / 50°; 17) *dulfīn* 311° / 30°; 18) *ra's al-faras* 316° / 23°; 19) *ʿunuq* 340° / 38°. These names are not always the full name of the star and in some cases exact identification of the stars (or stars) intended is difficult. ... ."

Ernesto Canobbio. My indebtedness to Paul Kunitzsch is clear from his notes on the star-names, which are here reproduced here in full.[135] Previously it had not been possible to identify several of the stars on MUSA.

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135 A letter dated 14.04.2009 from Prof. Kunitzsch to Ernesto Canobbio was kindly forwarded to me on 03.09.2018 and enabled me to complete this analysis at least to my own (temporary) satisfaction. Here Pt stands for Ptolemy and UB for Ulugh Beg. Stars marked 'A' are of "indigenous, old-Arabic origin". The other names are derived from the Arabic translations of Ptolemy's *Almagest*. The stars were identified by Paul Kunitzsch as follows:

1. *surra*, "navel (of the horse = Pegasus)", α And ...
2. A *khaḍīb*, "the stained (hand of the Pleiades)", β Cas
3. *muthallath*, "triangle", α Tri
4. A *miʿṣam*, "wrist (of the hand of the Pleiades)", χ Per
5. *rukba al-yumnā*, "the right knee", (in correct Arabic it should be *al-r. al-y.*), the 16th star of Per = HR 1324, in UB λ 64°·46 and β 28°51
6. *fawq al-rukba*, "above the knee", the star immediately following no. 5 in Pt's and UB's star catalogues, 17th star of Per = λ Per, in UB λ 62°16, β 28°36
7. A *al-naʿsh*, "the coffin", γ UMA
8. A *qafza al-ūlā*, "the first leap (of the gazelles)" (in correct Arabic, ... *al-qafza*), ν (not ξ) UMa
10. *mankib*, "shoulder, δ Boo
11. A *fakka*, "(broken) dish", α CrB
12. A *al-rāmiḥ*, "the lance-bearing (*Simāk*)", the name is clearly that of the 1st magnitude star α Boo, whose coordinates in UB do not well fit the coordinates on the astrolabe here, especially longitude: α Boo has in UB λ 196°31, β 31°18 (which would fit)
13. *janb*, "side, flank", ε Oph [corrected in a **note**]. **Note** added: ... ... Of all of the stars (named *janb*) mentioned, only ζ Her could here fit, with regard to name (*janb*) and coordinates (in UB, λ 234°10, β 53°9, where ... '53' ... could also be misread as '13' in the Arabic script) ...
14. A *al-rāʿī*, "the shepherd", α Oph
15. *dhanab*, "tail ", ζ Aql
16. *minqār*, "beak (of the bird)", not "nose", β Cygni
17. *dulfīn*, "dolphin", ε Del
18. *ra's al-faras*, "the head of the horse": according to Pt and UB the first two stars of Equ are on the "head", α Equ being the "preceding one", and β "the following", ...
19. *ʿunuq*, "neck". In Pt and UB, two stars are on the "neck" of Pegasus, the 11th star (= ζ Peg) and the 12th star (ξ Peg). In UB their coordinates are: ζ Peg, λ 338°25, β 17°15; ξ Peg, λ 341°13, β 18°0. It looks as if ξ Peg is the most possible candidate; its longitude fits the value on the instrument, and the

An investigation of the stars on MUSA has already been undertaken by Ernesto Canobbio, but his study has not yet been published.[136] The present author has not used that study because he maintains that the positions of the star-pointers on MUSA should be measured again before any conclusions can be drawn from them.

The star-pointers on MUSA are arranged as follows: 1-4 are on the first inclined vertical quadrant; 5-6 are on the prominent vertical fork; 7-8 are on the second inclined vertical quadrant; 9-14 are on or near the semicircular frame to the left of the latitude scale; 15-19 are on or near the semicircular frame to the right of that.

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136 Canobbio, "On the Oxford spherical astrolabe", draft sent to this author on 03.09.2018.

LIST OF STARS ON THE MUSA SPHERICAL ASTROLABE AND THEIR ECLIPTIC COORDINATES

Notes: The star-names below are as interpreted by Francis Maddison and corrected and confirmed by the author. When only short forms are given, the full name is given where possible, then the modern identification and ancient/medieval magnitude **M**. This is followed by the longitudes and latitudes on the instrument as determined by Maddison. Separated from these by an asterisk are the coordinates of Ulugh Beg (UB). Correspondences in the coordinates within a few degrees are indicated in **bold font**. Comments indicating which star-names are also found on the ZAIM spherical astrolabe have been suppressed since it has become evident that these are of no historical interest.

First inclined vertical quadrant

1	سرة , *surra*	سرة الفرس , *surrat al-faras*, "the navel of the horse (Pegasus)", α Andromedae **M2-3** **8° / 26° * UB 6° / 25°**
2	خضيب , *khaḍīb*	الكف الخضيب , *al-kaff al-khaḍīb*, "the stained hand (of the Pleiades)", β Cassiopeiae **M3** **28° / 55° * UB 28° / 51°**
3	مثلث , *muthallath*	رأس المثلث , *ra's al-muthallath*, α Trianguli **M3** **34° / 16° * UB 30° / 16°**
4	معصم , *miʿṣam*	المعصم , *al-miʿṣam,* "the wrist of the outstretched right hand of the Pleiades", χ Persei **M nebula** **48° / 41.5° * UB 46° / 40°**

Prominent vertical fork

5 ركبة اليمنى , *(al-)rukba al-yumnā*	"the right knee (of Perseus)", Sø, b Persei **M4**, 16th star of Perseus; Canobbio suggests that this pointer is slightly bent **61° / 34° * 65° / 29°**
6 فوق الركبة , *fawq al-rukba*	"above the (right) knee", λ Persei **M4**, 17th star of Perseus **120°** (needs to be checked) / **37°** * UB 62° / 29° **PROBLEMATIC! Longitude too high by *ca.* 60° and latitude too high by *ca.* 10°**
First inclined vertical quadrant	
7 النعش, *al-naʿsh*	النعش , *al-naʿsh*, "the coffin", αβδγ Ursae Maioris **M2/3** **140° / 45° *** UB **143° / 47°** (αβδγ averaged)
8 قفزة الاولى , *qafza al-ūlā*	القفزة الاولى , *al-qafza al-ūlā*, "the first leap (of the gazelles)", ν Ursae Maioris **M3-4** **153° / 27° *** UB **150° / 26°**
Semicircular frame on left	
9 ساق , *sāq* (written as ساقا , dual)	ساق الاسد , *sāq al-asad* , "the shin-bone of Boötes", (rather than السماك الاعزل , *al-simāk al-aʿzal*, α Virginis (Spica) at 196°/-2°) η Boötis **M3** at UB 192°/28°; problematic identification **193° / 25° * UB 192° / 28° (shinbone)**
10 منكب , *mankib*	المنكب الايمن من العواء , *al-mankib al-ayman min al-ʿuwāʾ*, "right shoulder (of Boötes)", δ Boötis **M4-3** **208° / 50° * 205° / 49°**
11 فكة, *fakka*	المنير من الفكة , *al-munīr / al-munayyir min al-fakka*, "the bright star of the

(broken) dish”, α Coronae Borealis (Alphecca) **M2**
218° / 45° * UB 215° / 45°

12 الرامح , *al-rāmiḥ*

السماك الرامح , *al-simāk al-rāmiḥ*, “the lance-bearing *simāk*”, α Boötis (Arcturus) **M1**
230° / 32° * UB 197° / **31°**
PROBLEMATIC! The longitude is 30° too high for this, the only bright star in the list

13 جنب , *janb*

جنب الجاثي , *janb al-jāthī*, ζ Herculis **M3**
236° / 15° * UB 234° / 53°

14 الراعي , *al-rāʿī*

“the shepherd”, α Ophiuchi **M3**
257° / 35° * UB 255° / 36°

Semicircular frame on right

15 ذنب , *dhanab*

ذنب النسر الطائر , *dhanab al-nasr al-ṭā’ir*, “tail of the (flying) eagle”, “tail of the eagle”, ζ Aquilae **M3**
283° / 36° [!!] * UB 283° / 36°

16 منقار , *minqār*

منقار الدجاجة , *minqār al-dajāja*, “the beak of the chicken (Cygnus)”, β Cygni **M3-4**
300° / 50° * UB 294° / 49°

17 دلفين , *dulfīn*

ذنب الدلفين , *dhanab al-dulfīn*, “the tail of the dolphin (Delfinus)”, ε Delphini **M4-3**
311° / 30° * UB 306° / 29°

18 راس الفرس , *ra’s al-faras*

“the head of the horse (Pegasus)”, α and/or β Pegasi, both **M2-3**; Canobbio suggests that this pointer is slightly bent
316° / 23° * 315° / 20° and/or **317° / 21°**

19 عنق , ʿ*unuq*	عـنق الـفرس , ʿ*unuq al-faras*, “the neck of the horse (Pegasus)”, ζ and/or ξ Pegasi **M3-4** & **M4-5** **340° / 38° – UB 338° / 17°** and/or **341° / 18°** **PROBLEMATIC! Latitude is too high by 20°**

This is not a totally happy scenario. However, a new determination of the positions of the star-pointers would probably improve the situation. For further comments see below.

Analysis of various errors on MUSA

> “One man’s error is another man’s data.” Berman’s corollary to Robert’s axiom.

There are several problems with some of the star-names and the positions of their pointers on MUSA. Such a situation would be inconceivable on any Islamic planispheric astrolabe. But here we are dealing with genuine, if very rare, medieval instruments of a very complicated kind. Every error and every correspondence can tell us something.

The nature of some of the errors in the star-positions suggests that the maker of MUSA had access to a treatise containing a list of stars and their coordinates with longitudes expressed in SIGNS and degrees (and minutes?) and that the entries in this list were not arranged in order of increasing longitude. Some of the entries in this table were already corrupted by copyists or were illegible as a result of damage to the manuscript.[137] An alternative hypothesis would be that Mūsà Jālīnūs was copying an instrument on which these stars were already incorrectly marked. But at some earlier stage, there must have existed a spherical astrolabe with similar design on which the stars were marked properly.

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137 For the problems that modern researchers face with medieval Islamic tables using *abjad* notation see Kennedy & Kennedy, *Islamic geographical coordinates*, p. x; Kunitzsch, *Sternkatalog des Almagest*, I, pp. 19-21; King, *World-Maps for finding the direction and distance to Mecca*, pp. 161-163; and *idem* & Samsó & Goldstein, “Islamic astronomical tables and handbooks”, p. 19. The two worst examples recorded are discussed in Section 8 below.

The original stars on any prototype for MUSA, if there was one, relied on a star-list which put aesthetic considerations before practical ones, or before common sense. The pointers named simply منكب , *mankib*, "shoulder of" and ذنب , *dhanab*, "tail of" as well as the polysemous name ساق , *sāq*, "shin-bone", hardly inspire confidence. We find even ساقا , *sāqā*, "two shin-bones". The make was not doing potential users (or modern researchers) any favours. And readers should not assume that the maker of MUSA was simply well-versed in star-lore, for he most certainly was not.

This feature must have caused problems to anyone who might have tried to use this instrument. But this would hardly be the only problem. The only bright star of magnitude 1 is *al-rāmiḥ*, α Boötis, Arcturus. It is featured with the wrong longitude on MUSA, not 1° or 2° off, but 30°.

So how could one find one of several pointers marked, say, "tail", for a star of magnitude 4-5 that one has just identified with great difficulty (but whose altitude one cannot measure because there is no alidade or altitude scale)? The operation boggles the mind, and we can be certain that it was never carried out.

So in fact it was a rather shortsighted idea to select the stars for a spherical astrolabe after the model of the stars on a celestial globe. It would have been far more sensible to select the stars to the north of the ecliptic that were used on a standard astrolabe, and that is precisely what the authors of the Alfonsine treatise on the spherical astrolabe did. All of their 14 stars are bright stars. On MUSA, just one out of some 20 stars was a bright star.

We can identify two stars whose incorrect longitudes result from a misreading or a misrepresentation at some stage of the transmission of stellar coordinates:

(1) The star فوق الركبة , *fawq al-rukba* (MUSA-06), has a longitude too high by 60° (2 signs) and a latitude in the 30s that can be explained as a scribal error for 20s (ل for ك).

(2) The star السماك الرامح , *al-simāk al-rāmiḥ* (MUSA-12) has a longitude 30° too high.

We identify two other stars whose latitude on both instruments results from a misreading of stellar coordinates at some stage of the transmission:

(3) The star جنب الجاثي , *janb al-jāthī*, (MUSA-13) (ζ/ε Herculis) displays an error in latitude that is typical of the Arabic manuscript tradition.

Clearly, the value نــج , '53' in Ulugh Beg's table (or aa related table) has been misread or miscopied as يج , '13'.

(4) The star (الـفرس) عـنق , *ʿunuq* (*al-faras*) (MUSA-19), has a latitude some 20° too high. This perhaps derives from a misreading of the degrees of latitude يــز , '17', as لــز , '37', which would be another typical mistake in unpointed Arabic in the manuscript tradition.

The stars on MUSA may be divided into two main groups. Those on the basic ecliptic and the vertical stays and those on the supporting arcs, the latter being generally more accurate than the former. A future task of purely academic interest would be to investigate the way in which the stars on the principal supportive arcs on the rete might have been selected.

The positions of the star-pointers on MUSA were certainly not derived from Ulugh Beg's list, but rather from some other very corrupt earlier source. In particular, the accuracy of the markings is more accurate for those pointers on the circular arcs than for those on the base circumference (the ecliptic) and the four base circles. This means the latter – two different sets on each instrument – come originally from yet another source, even more corrupt than the first. Theoretically it would be possible to reconstruct the table(s) from which all of this stellar data was taken, but first the star-positions should be measured again properly. This preliminary analysis might then need to be adjusted accordingly, but this might be an exercise in futility. Certainly there are more urgent tasks awaiting investigators in the history of Islamic astronomy and instrumentation. On the other hand, some future investigator might try to reproduce the rete using three-dimensional computer graphics.

Peculiarities of orthography on MUSA

There are numerous peculiarities in the engraving on MUSA. It is not without interest to note the long list of orthographic and grammatical peculiarities that Robert Morrison has encountered in Mūsà's Arabic treatise on astronomy. There one is dealing with complete sentences rather than individual words, and, further, penning a manuscript can hardly be equated with engraving a metal object.[138]

On MUSA we find a medial عـعـع , *ʿayn*, with an inverted '*v*' on top; medial حـحـح , *ḥā'* looks like half of a coat-hanger; final , هـهـه *hā'* looks like a cross

138 Morrison, "Astronomical Treatise by Mūsā Jālīnūs", pp. 388-390.

between a Greek lower-case λ, *lambda,* and a giraffe; and medial عـــعع , ʿ*ayn*, generally has no top.

In star name #7: الـــنعش , *al-naʿsh*, however, the medial عـــعع , ʿ*ayn*, has an inverted '*v*' on top, possibly to avoid there being a succession of five consecutive vertical strokes (one for the medial نــــن , *nūn*, two almost vertical for the medial ععع *,* ʿ*ayn*, and three for the final ش , *shīn*. The bowl of the final س , *sīn* (for ش , *shīn*), in this star-name is too small.

The word المشـــرق , *al-mashriq*, "east" on the sphere is engraved with a defective (too small) medial مـــمم , *mīm* and a defective medial ســـسس , *sīn* (for شـــشش , *shīn*), with two rather than three vertical strokes, a third one serving the following ر , *rā'*.

Alas, we have for comparison no example of Mūsà's Arabic calligraphy in any known manuscript, only his additions in Hebrew to the unique manuscript of his Hebrew treatise "On Life's Puzzles".

6 Who was Mūsà?

Muslim astronomers named Mūsà from the period 1200-1600

> “ ... it seems that this instrument [MUSA] poses more than one problem, beginning with the maker’s name “Mūsā” which, in this short and abbreviated form, obviously cannot be identified with any of the known astronomers or instrument makers of the period (885H / 1480/81). ... ” Paul Kunitzsch in a letter to Ernesto Canobbio dated 26 March, 2009.

As we shall see, the more information we can derive about this instrument, its maker and the milieu in which it was made, the better position we shall be in to confront the next, recently rediscovered example. We have already noted that the instrument comes neither from the Eastern Islamic world nor from the Western. In Egypt and Syria in the 14th and 15th centuries it was often the astronomers themselves who constructed instruments. When they did this, they would usually sign their full names. We therefore consider the various Muslim astronomers from the period who bore the name Mūsà. If we can find one at latitude 41° around the year 1480 we can assume that out mission is accomplished.

Kamāl al-Dīn Mūsà ibn Yūnus (1156-1242), the well-known author on optics and aspects of mathematics, was born in Mosul, studied in Baghdad, and then returned to Mosul to teach.[139] Two of his works deal with instrumentation on two different levels: a commentary on the linear astrolabe of his teacher Sharaf al-Dīn al-Ṭūsī,[140] and a trivial candle-clock for regulating the seasonal night-hours.[141] His dates are too early for our purposes.

There was another Mūsà who was a well-known astronomer in Damascus *ca*. 1400. This is Sharaf al-Dīn Mūsà ibn Muḥammad al-Khalīlī.[142] a nephew of the more distinguished Damascus astronomer Shams al-Dīn al-

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139 # On this Ibn Yūnus see n. 16 above.

140 # Michel, “L’astrolabe linéaire d’al-Tusi” (1943); on this al-Ṭūsī see n. 15 above.

141 Kennedy *et al*., *Studies*, pp. 499-501 (text associated incorrectly with the earlier Egyptian astronomer Ibn Yūnus).

142 # On Sharaf al-Dīn al-Khalīlī see n. 37 above.

Khalīlī.[143] He wrote treatises on the standard instruments of his milieu. He also wrote on a lesser-known and more sophisticated مستتر , *musattar* quadrant for Damascus, on which some of the altitude circles are folded over onto the other ones in order to ensure that all the astronomical markings fit exactly onto the quadrant. He is alas also a century too early for the spherical astrolabe now in Oxford.

Then there is the prolific astronomer Ṣalāḥ al-Dīn Mūsà ibn Muḥammad ibn Maḥmūd known as Qāḍī Zade, who was born in Bursa *ca*. 1360 and died in Samarqand after 1440.[144] He is not known to have written on instruments for it is not certain that the treatises on the trigonometric and astrolabic quadrants that are attributed to him in various manuscripts are in fact by him. More important for our present concern, he too is about half a century too early.

A certain Mūsà ibn Ibrāhīm, otherwise unknown, wrote a short treatise on the standard astrolabe which is extant in MS New York Columbia 285,1 (fols. 1v-8r, copied *ca*. 1600).[145] Two other Egyptian astronomers with the name Mūsà are both too late for candidature.[146]

This author has published extensively on the activities of Muslim astronomers in Mamluk Egypt and Syria (13th-16th C.), having inspected

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143 # See Suter, *Mathematiker und Astronomen*, no. 418; King, articles in *DSB* and *BEA*; *idem*, *Cairo Survey*, no. C37; *idem*, *Synchrony*, II: 359-401, for a survey of all his tables; and a selection of articles available on www.muslimheritage.com/article/al-khalili-spherical-astronomy. See also n. 67 above.

144 Suter, *Mathematiker und Astronomen*, no. 430; King, *Cairo Survey*, no. G50; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 808; article in *BEA* by Jamil Ragep.

145 King, "Origin of the astrolabe according to the Arabic sources", p. 55, and p. 595 of the version in *Synchrony*.

146 (1) Mūsà ibn Muḥammad ibn Mūsà al-Qulaybī al-Ghamrī – King, *Cairo Survey*, no. D71; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 1275, author of an astrological treatise. (2) Mūsà ibn Shāhīn al-Abshādī al-Muslimī al-Ḥusaynī, 17th-century astronomer who wrote on prayer-times and eclipses – King, *Cairo Survey*, nos. D33 & D167; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 1231.

hundreds of relevant manuscripts and dozens of instruments.[147] No candidate from this milieu presents himself as a possible maker of the Oxford instrument. Also, François Charette has contributed substantially to the documentation of Mamluk astronomers.[148] Likewise, Sonja Brentjes has analyzed all of the biographical references to astronomers associated with religious institutions in Cairo and Damascus, mainly in that period.[149] There is no mention in her medieval sources of those who constructed instruments or of anyone called Mūsà except al-Khalīlī's nephew mentioned above, who, according to his biographers, seems to have concentrated on theoretical astronomy anyway.

Mūsà Jālīnūs

> " ... The Jewish scholar Moses Galeano, who also wrote under the Arabic and Turkish name Mūsà Jālīnūs, was an extraordinary person, crucial because he truly straddled both worlds. He identified as a Jew but you wouldn't always know it. He was extremely well informed and was familiar with the Ottoman court as well as elites in Venice. He brought some really high-level Islamic astronomy to Venice and Padua, but he also translated a Latin astronomy text into Arabic for a high-ranking Ottoman judge and wrote a text in Ottoman Turkish that reported on Latin medical texts. ... " Robert Morrison (2018) at http://community.bowdoin.edu/news/2018/04/robert-morrison-awarded-presitigous-fellowship-to-study-islamic-influence-on-the-renaissance/ (site accessed 2018). Add to that the Oxford spherical astrolabe.

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147 See, for example, the authors listed in King, *Cairo Survey*, Sections C and D; also *idem*, "Astronomy of the Mamluks" (1983), and "L'astronomie en Syrie" (1993); also *In Synchrony with the Heavens*, *passim*, and *Catalogue of medieval Islamic instruments*, 1.5.

148 Charette, *Astronomical instrumentation in 14th-century Egypt and Syria* (2003), and *idem*, "The Locales of Islamic astronomical instrumentation" (2006).

149 Sonja Brentjes, "Shams al-Dīn al-Sakhāwī on muwaqqits, mu'adhdhins, and astronomy teachers in Mamluk cities" (2008), and *eadem*, "On four sciences and their audiences in Ayyubid and Mamluk societies" (2017).

> "Virtually nobody accepted my interpretation. This surprised me not in the least. ... ... I have always thought that an inclination towards audacious hypotheses is and should be perfectly consistent with rigorous research into the evidence." Carlo Ginzburg, *The Enigma of Piero* (2000), pp. 118 & 120, cited in King, *Astrolabes and angels, epigrams and enigmas* (2007), p. 187.

We come now to a candidate who is at once the most likely and also the most unlikely maker of the Oxford spherical astrolabe instrument. The only reason a maker would sign himself only "Mūsà" would be that he was generally known by that name alone, or by that name and an epithet which was superfluous on a maker's inscription on an astrolabe, or if that name alone was also sufficient at the time for him to be identified as the maker. Perhaps the maker may have come from a milieu where a given individual might have two distinct names, or two names in different languages.[150] Mūsà is not only a common Arabic name, it is of course the Arabic rendering of the Hebrew name Moshe, a principal figure of the *Torah* / Old Testament, as well as in the *Qur'ān*. Muslim scholarship sees him as perhaps the most significant of the prophets prior to Muḥammad.

A certain Moshe Galeano ben Yehuda, who wrote in Arabic under the name Mūsà Jālīnūs ibn Yahūda, is known to us as a physician, astronomer and translator.[151] He would have been a young man around 1480. His Arabic epithet is the name of the celebrated 2nd-century Greek scholar of

150 On the astrolabe dedicated by 'Ioannes' to (Cardinal Basileios) Bessarion in Rome in 1462, the Ioannes is the German astronomer Regiomontanus. However, Bessarion also adopted the name Ioannes, probably because the letters IOANNES are contained in the name BESSARION. The dedication is a brilliant play on the letters IO, the standard Latin abbreviation for Ioannes. See further King, *Astrolabes and angels*, pp. 13-14 and 259-274.

151 On Mūsà Jālīnūs see Krause, "Stambuler Handschriften", p. 520 (no. 22); King, *Cairo Survey*, no. H3; Rosenfeld & İhsanoğlu, *Mathematicians & Astronomers*, no. 948; İhsanoğlu *et al*., *Ottoman astronomical literature*, I, pp. 224-225 (no. 102). These contain references to the earlier literature by M. Steinschneider mentioned below. See further below for recent studies of Mūsà's four major works.

medicine Galen.[152] For our present purpose, nothing is known of Moshe's youth until in our sources he appears in Istanbul[153] about the time of the accession of Ottoman Sultan Bāyāzīt II (1481).

There is some confusion about our Moshe / Mūsà in the literature. Sometimes he is confused with others, and occasionally Mūsà Jālīnūs and Moshe Galeano surface as two different individuals.

Although Moshe / Mūsà was in Istanbul, he also seems to have had a connection with the Venetian Republic of Candia, that is Crete, whither he repaired later in life.[154] He names Elijah Mizraḥi, who served as rabbi in Istanbul in the first quarter of the 16th century, as one of his teachers (see below). It seems that he did spend most of his life in the Ottoman capital.

Now Moshe / Mūsà may well have come into contact with two treatises on the spherical astrolabe that were in the library of Sultan Bāyazīt II and are now in the Topkapı Palace Library. These were supposedly authored by Ḥabash al-Ḥāsib and Ḥāmid ibn ʿAlī al-Wāsiṭī. The first was the leading astronomer of 9th-century Baghdad and the second the leading instrument-maker there *ca*. 950.[155] Preliminary research has established that the first treatise has nothing to do with Ḥabash – see above.

We may well ask why Mūsà adopted the name of Galen as part of his own name in Arabic. This would appear to be extremely presumptuous for any medic. But apparently the name was applied – in the form of "the Galen and Hippocrates of the age" – to the Ottoman Sultan's personal doctor on

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152 See, for example, the article "D̲jālīnūs" by Richard Walzer in *Encyclopedia of Islam*, 2nd edn., and "Câlīnūs" by İlhan Kutluer in *İslâm Ansiklopedisi*, vol. 7 (1993), pp. 32-34.

153 The name 'Istanbul' rather than the Arabic name 'Qusṭanṭīniyya' is used throughout this paper since it deals mainly with the city after the conquest of 1453. The latter was still being used even in the early 16th century by the historian Taşköprüzāde, when writing about the mystic Sheykh Vefā, author of well-known calendar and prayer-tables (*ruznāme*), who died during the reign of Bāyazīt II – see King, *In Synchrony with the Heavens*, II: 440-443.

154 Shefer-Mossensohn, *Science among the Ottomans*, p. 119, incorrectly assumes he came from Crete.

155 # See the text to nn. 14 and 17 above for references to the Topkapı manuscripts.

formal occasions.[156] However, our Mūsà did not have that noble office. Rather, he gives the impression in the stories which he relates in his *Puzzles* (see below) that he was involved with the military. He also wrote his canons for Zacuto's perpetual almanac (see below) at the behest of a leading figure in the military. This suggests therefore that Galeano was his Hebrew family name, and it was simply rendered as Jālīnūs in Arabic. Indeed, he actually mentions that his grand-father bore the name Rabbi Eliah Galeano.[157] One may wonder what the names Galeano or Galliano (written גאלינו , *g-'-l-y-n-w* or גאליינו , *g-'-l-y-y-n-w* in Hebrew) and Jālīnūs (written جالينوس , *j-'-l-y-n-w-s* in Arabic) can tell us further.

In passing, we note that Jewish astrolabists in the Islamic world and in medieval Europe did not sign the instruments they made and engraved with Hebrew or Judaeo-Arabic inscriptions.[158] In fact, Mūsà's spherical astrolabe in Oxford is the only one known out of perhaps a dozen surviving instruments of this kind, the rest all planispheric astrolabes, that has been signed by its Jewish maker.

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156 Russell, "Physicians at the Ottoman court", p. 265. See also Morrison, "A scholarly intermediary between the Ottoman Empire and Renaissance Europe", p. 37, n. 26.

157 Langermann, "Medicine, mechanics and magic from Moses Galeano's *Taʿalumot hokmah*", p. 376.

158 For a list of astrolabes with Hebrew inscriptions see King, *Astrolabes from medieval Europe*, XII: "An ordered list of European astrolabes to *ca*. 1500", esp. pp. 6-7. For discussions of the problematics of maker's names see King, "Astrolabe from 14th-century Christian Spain with inscriptions in Latin, Hebrew and Arabic", pp. 102-113, and Abu Zayed *et al*., "Enigmatic Judaeo-Arabic astrolabe", p. 104 (Abraham or Moshe!). See also "Astrolabes in Medieval Jewish Culture" (2014), at http://blogs.mhs.ox.ac.uk/hebrew-astrolabes/ (accessed 2017), and Rodríguez-Arribas, "Medieval Jews and medieval astrolabes: Where, why, how, and what for?" (2013).

7 Sultan Bāyazīt II and his interest in astronomy

> "The history of astronomy in Ottoman Turkey is a much neglected area of the history of Islamic science." DAK, "Astronomical timekeeping in Ottoman Turkey" (1977), p. 245. (This paper, published in Istanbul, was not cited for about 40 years by anybody who wrote on the history of Ottoman science.)

> " ... I have not been able to find any academic studies of this early chapter in Ottoman science, particularly with regard to Bayazid II." Tzvi Langermann, "A compendium of Renaissance science ... by Moses Galeano" (2007), p. 5.

> "With respect to the trends in modern Ottoman studies, the dearth of scholarly interest in Ottoman astrological materials is not surprising indeed, given the fact that throughout the almost century-long history of modern Ottoman historiography, cultural and intellectual history as well as the history of science have attracted much less attention as opposed to the political, social, and economic history." Tunç Şen, *Astrology in the service of the Empire* (2016), p. 5. The same is true of Ottoman astronomical materials.

The reign of Bāyazīt II (1481-1512) was hardly a time of peace and prosperity, with military campaigns in the Balkans, as far as the Crimea, and in Syria and Egypt against the Mamluks, as well as the threats from Europe and from Persia, and, not least his own murderous actions against his brothers and their male offspring.[159] It was this Sultan who graciously and thoughtfully invited Jews who had been expelled from the Iberian Peninsula to seek refuge in the Ottoman Empire. We shall return below to some other Jewish scholars concerned with astronomy.

Bāyazīt II had a personal interest in astronomy & astrology and possessed a remarkably rich library of works on the subject, many of which are fortunately still preserved in the Topkapı Palace Library. A late-15th- or early-16th-century catalogue of the many hundreds of manuscripts in the Sultan's library, now preserved in Budapest, is currently being studied by

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159 The article "Bāyazīd II" in *Encyclopedia of Islam*, 2nd edn., by V. J. Parry concentrates on such "history", to the exclusion of anything cultural or academic.

an international team commissioned by the Hungarian Academy of Sciences.[160] It is a document of extreme importance and one can hope that it will be soon accessible to scholars. As always with medieval scientific manuscripts, a simple 'author and title' list will be inadequate to reveal some of the most interesting and historically significant contents. But once the scholarly world is informed of this treasure trove, it is to be hoped that serious interest in Bāyazīt II and Islamic science in general may be awakened. This having been said, the Topkapı Library has been open to scholars for decades, and reliable catalogues of the holdings of Arabic, Persian, and Turkish manuscripts are readily available. Nevertheless the number of scholars who have used any of these to further our knowledge of the history of Islamic science over the past century can be counted on one hand.

Astronomy was not the only interest of the Sultan, but it goes beyond the scope of the present study to dwell on his other interests. Sean Roberts' new book *Printing a Mediterranean World – Florence, Constantinople, and the Renaissance of Geography* deals with maps associated with Bāyazīt II. Indeed, it begins with the words "In the winter of 1483 an apparently unexpected gift arrived in Constantinople at the court of Sultan Bayezid II, son of Mehmed the Conqueror ... ."[161] We shall also not discuss the Sultan's prohibition of the printing of Arabic script in 1483, whereby the Shaykh al-Islām issued a *fatwa* stating that moveable-type printing was permissible only for non-Muslim communities, but not for Muslims of the Empire.[162] This effectively ensured that Ottoman astronomy remained essentially medieval for several centuries thereafter, its only escape being the introduction of new European '*zīj*es' in Turkish, available only in manuscript form.

Byzantium, in particular Constantinople, had been a centre of activity in astronomy for about a millennium before the Ottoman conquest. Many texts were written and many more copied, but this was not the most

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160 Miklós Maróth, "The Library of Sultan Bayazit II".

161 Roberts, *Printing a Mediterranean World – Florence, Constantinople, and the Renaissance of Geography,* p. 1. See also Manning, *European cartographers and the Ottoman world 1500-1750*; and Offenberg, "The printing history of the Constantinople Hebrew Incunable of 1493".

162 Ghali, "Printing Press in the Ottoman Empire", p. 6.

exciting astronomical tradition that the world had ever seen.[163] Greek scientific initiative had long dried up although there was a modest increase of serious activity in the 11th century, not least on account of the arrival of various Islamic works. As far as Byzantine instruments were concerned, several portable sundials have survived from this tradition[164] and one solitary astrolabe with Greek inscriptions.[165] This, an elegant and comparatively large presentation piece, was made in Constantinople in 1062 for Sergios, a government official of Persian origin. This last feature has given rise to the fiction, now gospel, that the sole surviving Byzantine astrolabe shows Islamic influence, but in fact it shows none. To be more precise, the decoration that has been taken to indicate Persian or Islamic influence is strictly Byzantine; the star-positions, on the other hand, are influenced by Islamic star-tables, otherwise they would be wildly incorrect. There is, however, evidence which suggests that the astrolabe was taken from Constantinople to Rome in 1440 by Cardinal Bessarion and thence to Vienna in 1460, where the Cardinal showed it to the young German astronomer Regiomontanus, who was inspired to make a spectacular little astrolabe which he presented to the Cardinal in Rome in 1462 in order to replace the 1062 piece but also to celebrate its 400-year anniversary. Small solace for the Cardinal, whose native Trebizond was captured by the Turks in 1461.[166]

Influences of regional schools

Islamic astronomy, after the initial period of 'acquisition and assimilation' in Iraq and Greater Iran during the 8th-10th centuries, was essentially regional, each tradition having its own authorities and own particular interests. Ottoman astronomy was influenced by three major regional schools of astronomy:

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163 For a survey see Jones, "Later Greek and Byzantine astronomy" (1996).

164 See, for example, Field & Wright, "Gears from the Byzantines" (1985).

165 Dalton, "The Byzantine astrolabe at Brescia" (1926), also Stautz, "Die früheste Formgebung der Astrolabien" (1994). The title King, "Byzantine astrolabe of 1062", serves only to guide to the material in the next footnote.

166 On the two astrolabes of Bessarion see King, *Astrolabes and angels*, pp. 13-46, and 220-233, 259-274.

(1) The Iranian school, characterized by theoretical astronomy and observational astronomy, as represented by the activities of the astronomers at the Observatory of Maragha (N. W. Iran) *ca*. 1250 under the polymath Naṣīr al-Dīn al-Ṭūsī (b. Tus, 1201, d. Baghdad, 1274).[167] Among the major works produced there which were important for Ottoman astronomy is the Persian handbook with tables زيج إيلخاني , *Zīj-i Īlkhānī* or *Īlkhānid Zīj*,[168] but more so al-Ṭūsī's well-known treatise on astronomy, التذكرة في علم الهيئة , *al-Tadhkira fī 'ilm al-hay'a*, "A memento on astronomy", produced at this time.[169] The latter was commented upon with commentaries and commentaries upon commentaries mainly in the region of Greater Iran.

(2) The Central Asian school, itself influenced by the Maragha school and culminating in the activities under the ruler Ulugh Beg (b. Sultaniyya, 1394, d. Samarqand, 1449) at the Samarqand Observatory during 1420-1450.[170] By far the most important work produced there was the monumental Persian زيج سلطاني , *Zīj-i Sulṭānī*, *Sulṭānī Zīj* or, simply, the *Zīj* of Ulugh Beg; this was to be adapted to other longitudes from Algiers to Delhi, including Istanbul. An influential but not particularly innovative member of the Samarqand team was Qāḍī Zāde al-Rūmī (b. Bursa *ca*. 1359, d. Samarqand, after 1440). An earlier very popular brief 'Islamic' introduction to Ptolemaic astronomy, الملخص في الهيئة , *al-Mulakhkhaṣ fi 'l-hay'a*, "An abridged treatise on astronomy", by a rather mysterious Maḥmūd ibn ʿUmar al-Jaghmīnī, compiled in Central Asia at the

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167 On the Maragha Observatory see Sayılı, *The Observatory in Islam*, pp. 187-223. On al-Ṭūsī see the article in *BEA* by Jamil Ragep, and also Aydüz, "al-Ṭūsī's influence on Ottoman scientific literature".

168 On this work see Storey, *Persian literature*, II:1, pp. 58-60; Boyle, "The longer introduction to the *Zīj-i Īlkhānī*"; Kennedy, "Survey of Islamic Astronomical Tables", pp. 3, 39-40; King & Samsó & Goldstein, "Astronomical handbooks and tables from the Islamic world (750-1900)", pp. 46-47, 53.

169 On al-Ṭūsī see the article by F. Jamil Ragep in *BEA*. Ragep, *al-Ṭūsī's* Tadhkira, is a model critical study of a text that was constantly modified by its author over more than a decade, with text, translation and commentary.

170 # On the activities of the Samarqand Observatory see Sayılı, *The Observatory in Islam*, pp. 223 and 258-289; and, more recently Fazlıoğlu, "The Samarqand Mathematical-Astronomical School". On Ulugh Beg see the article in *BEA* by Benno van Dalen. See further below – n. 253.

beginning of the 13th century, was to have resounding success in Ottoman Turkey and elsewhere, both in its origin form and in commentaries such as that of Qāḍī Zāde, and super-commentaries.[171]

(3) The Syro-Egyptian school, characterized by theoretical astronomy and practical solar, lunar, planetary astronomy, as represented mainly by Ibn al-Shāṭir of Damascus *ca*. 1350, and astronomical timekeeping and instrumentation, as represented by his contemporary al-Khalīlī of Damascus and various others in Cairo, Damascus and Aleppo.[172] Not only الزيج الجديد , *al-Zīj al-jadīd*, *'New' Zīj* of Ibn al-Shāṭir, with its 'new' solar, lunar and planetary models, in different recensions, but also all manner of tables for timekeeping and regulating the times of prayer, and numerous varieties of astrolabes, quadrants and sundials, came to Istanbul from Egypt and/or Syria.

In addition to the main relevant works we should mention the annual ephemerides, tables displaying the positions of the sun, moon and five naked-eye planets for each day of a given year. The positions would be computed in advance using the tables of a *zīj* or astronomical handbook with tables and explanatory text. Usually the astrological implications of the relative positions of the celestial bodies would be indicated in three ephemerides. To mention the associated astrological literature we would go beyond the framework of the present study.

Pre-Ottoman Seljuq and Ottoman astronomy in Anatolia before the conquest of Constantinople in 1453 are even more neglected subjects than Ottoman astronomy after 1453.[173] The most important astronomer in this region during this period was Quṭb al-Dīn al-Shīrāzī, born in Shiraz in 1236. He had worked at the Observatory of Maragha, and was a leading figure in developments in theoretical astronomy. He compiled some of his

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171 S. Ragep, *Jaghmīnī's* Mulakhkhas, for the edited Arabic text, a translation and an exhaustive commentary.

172 For an overview of astronomy in Egypt and Syria in the period 13th-16th century, see King, "Astronomy of the Mamluks".

173 Sayılı, *The Observatory in Islam*, pp. 253-255, does not present any independent works from Anatolia. The interested reader may check İhsanoğlu *et al*., *History of Astronomy Literature during the Ottoman Period* (in Turkish).

most important astronomical works in Konya, Sivas and Malatya around 1275, and he died in Tabriz in 1311.[174]

Two independent Karamanid (post-Seljuq) works from Anatolia dealing with astronomical timekeeping are known.[175]

The first is a set of tables for regulating the times of prayer for an unspecified locality with latitude 38°30′; these are in the same style and format as the earlier tables of Ibn al-Shāṭir and al-Khalīlī for various locations in Syria (although they use obliquity 23°35′ rather than the 'new' value of the Syrian astronomers 23°31′). They are found in the unique copy MS Istanbul Süleymaniye 1037,32 (fols. 282v-285v).

The second is a very remarkable set of tables for the same purpose and for latitude 38°, copied in Sivas in 773 H (1371/72) by Zayn (al-Dīn) al-Munajjim ibn Sulaymān al-Qūnawī, an astronomer in Konya. They are found in MS Istanbul Nuruosmaniye 2782. Another copy of these tables is appended to the unique copy MS Cambridge Browne O.1, fol. 179r, of the Persian *Zīj-i Mufrad* of the 11th-century astronomer Muḥammad ibn Ayyūb al-Ṭabarī.[176] The tables are of a kind not attested in any other Islamic source, and the definitions for the times of prayer are different from the standard ones and are therefore of great historical interest.[177]

I know of no more such independent pre-Ottoman Anatolian works on any aspect of astronomy. We therefore return to the Ottomans in the late 15th century.

Early Ottoman astronomy

It is beyond the scope of the present study to dwell on the astronomical interests of Sultan Meḥmet II, also known Fātiḥ Meḥmet or Meḥmet "The

174 See the article "al-Shīrāzī" in *BEA* by F. Jamil Ragep.

175 King, *In Synchrony with the Heavens*, II: 438-440, and IV: 573-575.

176 See Kennedy, "Survey of Islamic astronomical tables", no. 65; Storey, *Persian Literature*, II:1, pp. 3-4 and 43-44; and King & Samsô & Goldstein, "Islamic astronomical handbooks and tables", p. 42.

177 Tunç Şen refers to them as a *taqwīm*, but this they are not. However, it was probably how they were catalogued in the library handlists in the 1970s, which explain how this author found them in the first place. See Şen, "Reading the stars at the Ottoman Court: Bāyezīd II (r. 886/1481-918/1512) and his celestial interests", p. 572.

Conqueror", so we shall now concentrate on works that were dedicated to his son and successor Sultan Bāyazīt II. This is important not only for understanding the spherical astrolabe from Istanbul that is discussed in this paper, but not least because many modern works on the history of Ottoman astronomy simply start a century later with the Istanbul Observatory of Taqi 'l-Dīn in the late 16th century, which is fairly well documented.[178]

Two scholars who had spent time at the Observatory in Samarqand and moved to Istanbul were influential for Ottoman science. The first was the prominent astronomer and polymath ʿAlī Qūshjī who arrived in Istanbul in 1472 indirectly from the Observatory at Samarqand, where he had assisted in the observations under Ulugh Beg, but he died in Istanbul in 1474.[179]

We also find traces of the less prolific Fatḥallāh Shirwānī, who was born in Shirwan (Azerbaijan) in 1417 and who returned there from his travels in 1478 and died there in 1486. He spent five years studying at the Observatory in Samarqand before moving in 1440 to teach in Anatolia. He was author of a commentary on the *Takhkira* of al-Ṭūsī, which he tried unsuccessfully to dedicate to Meḥmet II in 1473, and a super-commentary (حاشية , *ḥāshiya*) on al-Jaghmīnī's *Mulakhkhaṣ*.[180] These were important less for their content than for their future role in astronomy education in Ottoman Istanbul.

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178 On Taqi 'l-Dīn (b. Damascus 1526, moved to Istanbul in 1570, died there 1585), who was steeped in the vibrant astronomical traditions of Syria and Egypt, see the article by İhsan Fazlıoğlu in *BEA* and the works there cited. Also useful is Fazlıoğlu, "Taqi al-Din Ibn Ma'ruf: Survey on his works and scientific method". On a prolific contemporaneous Istanbul, Muṣṭafà ibn ʿAlī, whose works were, for better or for worse, very popular, see the same author's article in *BEA*.

On the observatory in Istanbul see Sayılı, *The Observatory in Islam*, pp. 289-305; Ünver, *İstanbul rasathanesi*, *passim*; and on the observational instruments see Tekeli, "The comparison of the instruments of Taqī al Dīn and Tycho Brahe", "The astronomical instruments of *Zīj-i-Shāhinshāhīya*", and "Observational instruments of Istanbul Observatory".

179 See the article "Qūshjī" in *BEA* by Iḥsan Fazlıoğlu.

180 See the article "Shirwānī" in *BEA* by Iḥsan Fazlıoğlu, and a new study of optics and geography in his astronomical works in Trigg, "Astronomical commentaries of Fatḥallāh al-Shirwānī".

A new study by Ahmet Tunç Şen of scientific aspects of life at the early Ottoman Court has appeared in 2016.[181] This monumental doctoral thesis entitled *Astrology in the service of the Empire – Knowledge, prognostication, and politics at the Ottoman Court 1450s-1550s* raises the study of early Ottoman science to a new level, and the reader will find in it ample new information on the person of Bāyazīt II and his teacher Mīrim Çelebī, and the influence of the *Zīj* of Ulugh Beg at the Ottoman Court, as well as on the role of astrology in court life.[182] Numerous texts dealing with instruments – only astrolabes and quadrants – are signalled by Şen, but the only actual instruments mentioned are the two surviving astrolabes dedicated to the Sultan and some others that were in the Sultan's treasury, to which we shall return below.

The astronomer (and theologian) involved in teaching astronomy to the Bāyazīt II was apparently Maḥmūd ibn Muḥammad ibn Muḥammad ibn Mūsà Qāḍī Zāde known as Mīrim Çelebī. He was the great-grandson of Qāḍī Zāde, mentioned above. He was born in Istanbul in 1475 and died in Edirne in 1525.[183] He was well informed on the subject and wrote, in addition to a major work on theoretical astronomy, two works that he dedicated to the Sultan. The first, in Persian, was a treatise on a universal quadrant called (ungrammatically) ربع جامعة *rubʿ-i jāmiʿa*, not necessarily the sine quadrant, dedicated to the Sultan in 1494. The second, also in Persian, was a commentary on the *Zīj* of Ulugh Beg prepared at the Sultan's request and dedicated to him in 1498. In addition, Mīrim compiled his own treatises on the sine quadrant (ربع مجيب , *rubʿ-i mujayyab*); the astrolabic quadrant (ربع المقنطرات , *rubʿ al-muqantarāt*); the universal quadrant (ربع شكازي , *rubʿ-i shakkāzī*); and the universal plate

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181 Şen, *Astrology in the service of the Empire.* (I am grateful to Hasan Umut for drawing my attention to this work.) Şen's study of early Ottoman astrology marks a significant step forward and will be very important for future research. Some previous research has tended to begin the history of Ottoman astronomy with the Observatory of Taqī al-Dīn in the late 16th century.

182 I have not included here references to Şen's writings on these subjects.

183 On Mīrim Çelebī see Suter, *Mathematiker und Astronomen*, no. 457; Storey, *Persian literature*, no. 118; Rosenfeld & İhsanoğlu, *Mathematicians and astronomers*, no. 940; King, *Cairo Survey*, no. H4; İhsanoğlu *et al.*, *Ottoman astronomical literature*, I, pp. 90-101 (no. 47). A survey is in the article "Mīram Çelebī" in *BEA* by Ihsan Fazlioğlu.

(الزرقاله , *al-Zarqāla*) of Ibn al-Zarqālluh, who flourished in al-Andalus *ca*. 1100).

MS Istanbul Ayasofya 2618 is appears to be Bāyazīt II's personal copy of an anonymous treatise on the astrolabe in Persian. It bears the rather dubious title رساله الاسطرلاب المسمى باللباب في النجوم , *Risāla-yi al-usṭurlāb al-musammā bi-'l-Lubāb fī al-nujūm*, "Treatise on the astrolabe, entitled 'The Quintessence of (knowledge about) the stars'".[184]

The works of the great polymath of mid-13th-century Iran, Naṣīr al-Dīn al-Ṭūsī, were popular in Ottoman Turkey.[185] Yet only one version of a work of his seems to have been dedicated to Bāyazīt II. This is a Persian commentary on al-Ṭūsī's well-known Persian astrolabe treatise entitled بيست باب , *Bīst bāb,* "20 chapters". It was prepared by Muḥammad ibn Hacı ibn Suleymān al-Bursavī, also known as Efezāde (d. *ca*. 1495),[186] and was entitled simply شرح بيست باب در معرفة اسطرلاب , *Sharh-i bīst bāb dar ma'rifat-i asṭurlāb*, "A commentary on the '20 chapters' on the astrolabe". Curiously, there does not seem to have been a new version of al-Ṭūsī's well-known treatise on astronomy, التذكرة , *al-Tadhkira*, "A memento on astronomy", produced at this time.

The very popular introduction to Ptolemaic astronomy, الملخص في الهيأة , *al-Mulakhkhaṣ fi 'l-hay'a*, "An abridged treatise on astronomy", by al-Jaghmīnī, mentioned above, played an important role in this milieu, as did the well-known commentary on that work by Qāḍī Zāde dedicated to Ulugh Beg in 814 H (1412), on which Mīrim wrote a gloss. So did Sinān Pāshā (d. 1486) and Niksārī (d. 1495), who both dedicated their work to the Sultan. Qarā Sinān (d. 1480/81) dedicated his own commentary on the *Mulakhkhaṣ* to Bāyazīt II.[187] A Hebrew version of al-Jaghmīnī's treatise entitled ספר המזוקק, *Sefer ha-Mezuqqaq*, "The Purified Book", was prepared in Istanbul shortly after the Conquest of Constantinople by Meḥmet II in 1453, a few decades prior to the texts just mentioned here, by Moses ben Elijah Galeano called היוואני , *ha-Yewwānī* (?), surely,

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184 An significant anonymous Persian treatise on the astrolabe compiled in 1451 is in MS Cairo DMF 2, copied *ca*. 1500: see King, *Cairo Survey*, no. G119.

185 A survey of his works that were available in Ottoman Turkey is in Aydüz, "al-Ṭūsī's influence on Ottoman scientific literature".

186 Aydüz, "al-Ṭūsī's influence on Ottoman scientific literature", text to n. 42.

187 See S. Ragep, *Jaghmīnī's* Mulakhkhas, pp. 286-289.

היווני , *ha-Yewnānī*, “the Greek”. He has been identified by Robert Morrison with Moses ben Elijah Galeano, possibly related to our Mūsà Jālīnūs or Moshe Galeano.[188] This Moses Galeano is not known to have had any interest in instruments.

Tunç Şen has identified over 30 sets of ephemerides تقويم ج. تقاويم , *taqwīm* pl. *taqāwīm* prepared for individual years 894 to 917 Hijra (1489 to 1512), all dedicated to the Sultan.[189] An (Islamic) ephemeris shows positions of the sun, moon and five planets for each day of the (Hijra) year, with predictions about the visibility of the lunar crescent at the beginning of each month, and astrological predictions of one sort or another, often in the form of diagrammatic horoscopes. (Such ephemerides have a long history in Islamic astronomy, going back at least to the 9th century, if not earlier, for they were a common feature of late Greek Antiquity. They are often confused in the modern literature with agricultural almanacs and calendrical tables.) These early Ottoman ephemerides were computed either with solar, lunar and planetary tables converted to the meridian of Istanbul from either the *Zīj* of Ulugh Beg or the mid-13th-century *Zīj* of Naṣīr al-Dīn al-Ṭusī of Maragha.[190] Not one of these ephemerides was computed with the ‘perpetual’ auxiliary tables of Zacuto, for which Mūsà Jālīnūs had translated the instructions from Latin into Arabic.

Early Ottoman astronomical timekeeping

In the modern literature one often reads that medieval Muslim astronomers reckoned time and regulated the times of prayer using an astrolabe. In fact, extensive tables for time-keeping were available in most of the principal locations, as well as sundials, astrolabes and quadrants. Some works dedicated to Sultan Bāyazīt II which have been overlooked in the recent literature include the following sets of tables.

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188 This work is investigated in Morrison, “Oral transmission”, who implies a date posterior to the Ottoman conquest of Constantinople for this Galeano. S. Ragep, *Jaghmīnī’s* Mulakhkhaṣ, p. 291, has late 14th century, which is too early.

189 Şen, “Reading the stars at the Ottoman Court”, pp. 583-585.

190 Article “*Taqwīm*” in *Encyclopedia of Islam,* 2nd edn., by Michael Hofelich (ephemerides) and Daniel M. Varisco (agricultural almanacs). See also the illustrations in my article “*Ru’yat al-hilāl*”, and extracts for a full month and horoscopes in *Mathematical astronomy in medieval Yemen*, p. 95 and pls. 2-3.

First, الجدول الآفاقي , *al-jadwal al-āfāqī*, the "Universal table (for time-keeping)" of Shams al-Dīn al-Khalīlī of Damascus *ca*. 1360, the most sophisticated and most useful table for solving all of the problems of spherical astronomy for any latitude.[191] These tables were used in Syria, Egypt and Tunis, but also by Ottoman astronomers; nothing like them is known from pre-modern European astronomy, although they would have been very much appreciated by astronomers of the caliber of, say, Regimontanus. MS Istanbul Hamidiye 1453,3 (fols. 232v-266v) is a copy of these tables prepared in Edirne in 869 H (1464/65). Then in 897 H (1491) Muḥammad Kātib Sinān al-Qūnawī,[192] from Konya, the موقت , *muwaqqit* or professional timekeeper at the العتبة العليا , *al-ʿataba al-ʿulyā*, the "Sublime Porte",[193] prepared a Turkish version of the instructions to al-Khalīlī's tables and dedicated the ensemble to Bāyazīt II. The only copy of this version of al-Khalīlī's tables known to the author is MS Istanbul Süleymaniye Ayasofya 2590.

Second, the same Muḥammad Kātib Sinān al-Qūnawī prepared an enormous set of tables of some 500 pages and some 240,000 entries for timekeeping by night. This monumental work, entitled ميزان الكواكب , *Mīzān al-kawākib*, "The balance of the stars", was dedicated to Sultan Sulaymān ibn Sālim (reg. 1520-1566), grandson of Bāyazīt II.[194] These tables are extant in MSS Süleymaniye Ayasofya 2710 and Topkapı Ahmet III 3515

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191 # On al-Khalīlī see my articles in *DSB* and *BEA*, already mentioned in nn. 67 and 97 above. My 1973 study "al-Khalīlī's auxiliary tables" is superseded by the discussion in *In Synchrony with the Heavens*, I-9.4-5: 169-173, and II:10 "The Damascus corpus of al-Khalīlī": 359-401. On these Ottoman copies see *ibid*., I-9.5: 173 and II-14.6: 446.

192 On Muḥammad Kātib Sinān see Suter, *Mathematiker und Astronomen*, no. 455; King, *Cairo Survey*, no. H8; İhsanoğlu *et al*., *Ottoman astronomical literature*, II, pp. 84-90, no. 46; and the article "al-Qūnawī" in *BEA* by Iḥsan Fazlıoğlu.

193 Muḥammad Kātib Sinān is the first Ottoman astronomer known to us who bears this title. In the central lands of Islam the institution of the mosque astronomer or *muwaqqit* had been established in the 13th century, if not earlier: see King, *In Synchrony with the Heavens*, V: 623-678 "On the role of the muezzin and muwaqqit in medieval Islamic societies". Two Karamanid sets of tables for timekeeping show influence from Syria and from Iran, respectively: see *ibid.,* II: 438-440.

194 On these tables see King, "Astronomical timekeeping in Ottoman Turkey", pp. 248-249 and 250, and *idem*, *In Synchrony with the Heavens*, pp. 71-73 (I: 2.7.2) and 445 (II: 14.5).

(T 3046). In the tables one feeds in the normed right ascension (that is, المطالع من اول الجدي , ascensions measured from Capricorn 0°)[195] of a star that is culminating and the solar longitude and reads off: the time since sunset; the time remaining until sunrise; the time remaining until daybreak; and the time remaining until midday. No other tables of this kind are known from earlier Islamic astronomy (or from any other astronomical tradition).

Now if one feels the need to prepare tables for time-keeping by the stars then surely one would also prepare tables for time-keeping by the sun. Indeed Muḥammad Kātib Sinān also prepared such tables for time-keeping by the sun, extant in MS Istanbul Archaeological Museum 1255,4-5, fols. 156v-199a, copied *ca*. 1700, which have never been studied. The next known tables for Istanbul are of two different kinds, one by the celebrated astronomer Taqī al-Dīn in the late 16th century, and the other by one Aḥmet Efendī in the late 17th century, both sets for latitude 41°,[196] but there were surely earlier tables for Istanbul that have not been preserved, not least because there existed such tables in other major centres of the Ottoman Empire.

Before leaving the subject of timekeeping, we mention the 'almanac' (*ruznāme*) with tables for calendar conversion and for regulating the times of prayer for the latitude of Istanbul, taken as 41°30′ (accurately closer to 41°), by Muṣṭafà ibn Aḥmad al-Ṣīrawī (?)[197] al-ʿĪsawī, known as

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195 See my article "Maṭāliʿ [ascensions]" in *Encyclopedia of Islam*, 2nd edn.

196 On these two extensive sets of tables see King, "Astronomical timekeeping in Ottoman Turkey", pp. 248-249 and 250, and *idem*, *In Synchrony with the Heavens*, vol. 1, p. 64 (2.3.6) and p. 54 (2.1.7).

197 On Sheykh Vefā see İhsanoğlu *et al*., *Ottoman astronomical literature*, I, pp. 51-54. The question mark comes from King, *Cairo Survey*, no. H2. Alas no copy is at hand of MS Cairo K 4037,1 (fols. 1v-2r, copied *ca*. 1700), which contains the biographical notice published in my *In Synchrony with the Heavens*, II-14.3: 440-443. I should be very pleased if what I read many decades ago as الصيروي , "al-Ṣīrawī (?)" could be shown to be التيروي , al-Tīrawī, from Tire! However, İhsanoğlu *et al*. (p. 51) have الصدري , al-Ṣadrî.

Also, I wonder whether all of the tables in the almanac are due to Vefā. If the prayer-tables, which would demand far more mathematical competence than the calendrical tables, are not by him, I have not seen any evidence of the intervention by anybody else.

Sheykh Vefā (< Wafā').[198] He was a celebrated saint who lived during the time of Sultans Meḥmet II and Bāyazīt II. He compiled these tables whilst a prisoner of the Christians on Rhodes, but he was ransomed and returned to Istanbul, where he died in 896 H (1490/91). There are many extant copies of his tables, often in the form of a scroll. In addition to various calendrical tables, many copies of Shaykh Vefā's almanac contain tables for each degree of solar longitude (corresponding to each day of the year) نهار , *nahār*, the length of daylight; ليل , *layl*, length of night; ظهر , *ẓuhr*, time from sunrise to midday or midday to sunset; عصر , ʿ*aṣr*, time from midday to the ʿ*aṣr* prayer; مغرب , *maghrib*, time from the *ʿaṣr* to sunset; and عشاء , ʿ*ishā'*, the duration of evening twilight. Perhaps these tables were used at the Ottoman Court? Some 250 years later there appeared the prayer-tables for Istanbul, now with latitude 41°, by Darandelī (d. 1739).[199] In the meantime all manner of new and more extensive tables for timekeeping appeared on the scene of the موقتون (Arabic) or موقتلر (Turkish), the *muwaqqits* or *muvakkit*s of Istanbul.

Treatises on instruments

The same prolific scholar Muḥammad Kātib Sinān prepared several treatises, some dedicated to Bāyazīt II, on different kinds of quadrants. The astrolabic quadrant, ربع المقنطرات , *rub*ʿ*-i al-muqanṭarāt*, and the trigonometric quadrant, الربع المجيب , *al-rub*ʿ *al-mujayyab*, long popular in Egypt and Syria, were the most popular instruments in Ottoman astronomy for the next four centuries.[200]

Of greater historical interest is perhaps a work by the same scholar on the construction of horizontal sundials (رخامة ج. رخامات, *rukhāma*, literally, 'marble', pl. *rukhāmāt*) with tables of radial coordinates for marking the various curves on them, entitled simply كتاب في معرفة وضع الرخامات لعرض ما , *Kitāb fī waḍ*ʿ *al-rukhāmāt li-*ʿ*arḍ 41*°, "Book on the construction of horizontal sundials for latitude 41°". This is extant in MSS Istanbul

198 On these tables see King, "Astronomical timekeeping in Ottoman Turkey", pp. 247, and *idem*, *In Synchrony with the Heavens*, II-14.4: 444-445.

199 King, "Astronomical timekeeping in Ottoman Turkey", pp. 249-250, and *idem*, *In Synchrony with the Heavens*, II-14.4: 444-445. On the author see the article in BEA by Iḥsan Fazlıoğlu.

200 On quadrants see the article "*Rub*ʿ [= quadrant]" in *Encyclopaedia of Islam*, 2nd edn., and King, *In Synchrony with the Heavens*, X-6 "Quadrants": 71-80.

Topkapı A III 3501 (A 7121) and Cairo K 4059 (20 fols., copied 1059 H (1648/49)). Such a work would have led to a proliferation of sundials in the Topkapı Palace and in all of the major mosques in Istanbul.[201] Witness the sophistication of the horizontal sundial in the garden of the Topkapı Seray constructed during the reign of Sultan Meḥmet II, that is, *ca*. 1475, and renovated by ʿAbdallāh Silāḥdār in 1208 H (1793/94). The length of the rectangular marble slab is just less than a metre. The markings serve the seasonal hours of daylight and the equinoctial hours from sunrise and before sunset.[202]

We shall discuss below the treatises on instruments associated with Mūsà Jālīnūs.

The earliest surviving Ottoman astrolabes

Two astrolabes that were actually made for Sultan Bāyazīt II and dedicated to him are known to have survived. One is now preserved in the Museum of Islamic Art in Cairo. It bears Arabic and Persian inscriptions and was made by Shukrullāh Mukhliṣ Shirvānī in 910 H (1504/05). It has four plates for latitudes between 21° [Mecca] and 40°, then 41° [Istanbul]. The first inscription reads:

علمي وعملي شكر الله مخلص شرواني في تاريخ ٩١

ʿilmī wa-ʿamalī Shukrullāh Mukhliṣ Shirwānī fī ta'rīkh 91[0]

"Devised & constructed by Shukrullāh Mukhliṣ Shirwānī in 91[0]."

The precise meaning of the first two words, unique in the context of Islamic instrumentation, is not certain. Also, the dot representing zero has been omitted after the '91' in Hindu-Arabic numerals, which is unfortunate not least because Turkish instrument-makers would often leave out the '10' of a Hijra date '10xy', writing simply 'xy'. But the date 910 is certain because of the second inscription. The Persian dedication in two rhymed strophes reads:

رفعة سيارة و ثابت روان كرداد بديد \ كر كند طرف نظر سلطان اعظم بايزيد

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201 On sundials see the article "*Mizwala* [= sundial]" in *Encyclopaedia of Islam*, 2nd edn., and King, *In Synchrony with the Heavens*, X-7 "Sundials": 81-91. On Ottoman sundials see especially Meyer, "Sundials of the Osmanic era in Istanbul", and *Istanbul sundials* (in Turkish); and Bir, "Principle and use of Ottoman sundials".

202 For details see Meyer, *Istanbul sundials* (in Turkish), pp. 65-71; King, *In Synchrony with the Heavens*, I-7: 90 (fig. 7.2.9).

Rifʿat-i sayyāra vu thābit ravān gardād padīd
gar kunad ṭarf-i naẓar sulṭān-i aʿẓam Bāyazīd,

"If the greatest (of all sultans), Sultan Bāyazīd, casts a glance (at the sky with this astrolabe), the elevation of the planet(s) and the motion of the fixed star(s) will become manifest."

These inscriptions have already caused some confusion and the date 1091 has crept into the literature. This could happen because the dedication on this, the most important surviving Ottoman astrolabe, was also misinterpreted.[203]

The second astrolabe is now in the Islamic Art Museum in Doha, Qatar. It has Arabic inscriptions and was made by al-Aḥmar al-Nujūmī al-Rūmī in 911 H (1505/06).[204] The inscriptions read:

لرسم خزانة السلطان الاعظم السلطان بن السلطان
سلطان بايزيد بن محمد خان خلد (الله) ملكه

li-rasm [for *bi-rasm* ?] *khizānat ʻl-sulṭāni ʻl-aʿẓam al-sulṭān ibn al-sulṭān Sulṭān Bāyazīd ibn Muḥammad Khān khallada (Allāhu) mulkahu*

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203 Sezgin & Neubauer, *Science and technology in Islam*, vol. II: *Catalogue of the Collection of [copies of historical] instruments of the Institute for the History of Arabic and Islamic Science*, Frankfurt: IGAIW, 2011, p. 109: "An Ottoman Astrolabe. The instrument was made in the year 1091/1680 for a certain Sulṭān b. Aʿẓam b. Bāyazīd, probably a descendant of the Ottoman Sultan Bāyazīd II (d. 918/1512)." Although situated in Frankfurt, the late Prof. Sezgin was, of his own will, sadly out of touch with all contemporaneous research in Frankfurt on Islamic astronomical instruments.

204 Both are described in detail in King, "Two astrolabes for the Ottoman Sultan Bayezit II", with more information in *idem*, *In Synchrony with the Heavens*, XIVe (same title), 775-796. (The second piece was sold at auction in London by Sotheby's on 15.10.1998, and since that time, a substantial number of rather indifferent copies have been made in India, based on the auction catalogue illustrations. Several of these have appeared on the market.)

Leon A. Mayer and the present author are of the opinion that the first maker's given name was Mukhliṣ (see Mayer, *Islamic astrolabists snd their works*, pp. 15 and 83). On the other hand, Tunç Şen does not think Mukhliṣ is the maker's given name: however, his author Shukrullāh Shirvānī apparently appears on the scene elsewhere without any given name at all (see Şen, "Reading the stars at the Ottoman Court", pp. 600-601).

"By order of the treasury of the greatest sultan, sultan son of a sultan,
Sultan Bāyazīd ibn Muḥammad Khān,
may (God) make his dominion eternal."

صنعه الاحمر النجومي الرومي في سنة ٩١١ هجرية

ṣanaʿhu ʻl-Aḥmar al-Nujūmī al-Rūmī fi sanat 911 Hijriyya
"Constructed by al-Aḥmar al-Nujūmī al-Rūmī in the year 911 Hijra."

The three plates serve latitudes between 33° and 40°, then 41;30° [Istanbul]. The two instruments are quite different in character from each other and both are rather modest when compared with the more spectacular astrolabes that were presented earlier to Mamluk Sultans in Cairo and Damascus. They are also different from the rather uninspired astrolabes made by Turkish astronomers thereafter.[205]

The second maker is otherwise unknown to the modern literature, either on Islamic science or on Islamic astronomical instrumentation. However, in addition to the astrolabe, the same Shukrullāh Shirvānī presented Bāyezīt II with a compendium of sciences entitled رياض القلوب , *Riyāḍ al-qulūb*, "Gardens of the hearts", in which he discusses the meaning and benefits of "the science of the stars" علم النجوم , *ʿilm al-nujūm*, exclusively from an astrological perspective.[206]

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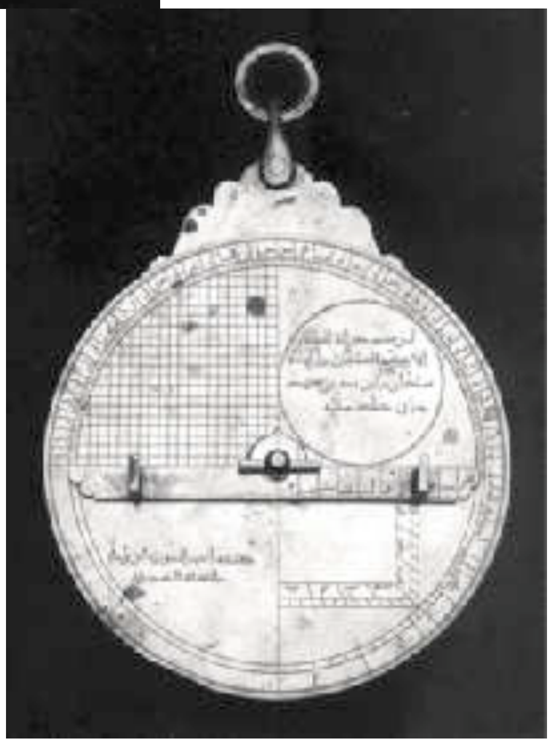
205 See King, *Catalogue of Islamic astronomical instruments*, §2.3.

206 Şen, *Astrology in the service of the Empire*, p. 184, n. 50, quoting MS Istanbul Süleymaniye Ayasofya 4024, fols. 62b-80b.

The Cairo astrolabe of Shukrullāh Shirvānī for Sultan Bāyazīt II. It is in the Iranian tradition of astrolabe-making, yet distinctively different from any known Iranian astrolabe. [Images from IGN-Archiv.]



The astrolabe of al-Aḥmar al-Nujūmī al-Rūmī for Sultan Bāyazīt II. It is in the Syrian tradition of astrolabe-making, yet much smore modest and far smaller than any such instruments dedicated to Ayyubid or Mamluk rulers. [Images from IGN-Archiv.]

An anonymous Persian version of a treatise, presumably written originally in Arabic, on the equatorium – a device for calculating the positions of the moon and planets – authored by Jamshīd al-Kāshī (d. 1429), the leading astronomer in Ulugh Beg's circle at Samarqand, was dedicated to Bāyazīt II. This treatise is extant in a Princeton manuscript (Garrett no. 75), which in 1960 was published by Edward S. Kennedy in facsimile with an English translation and commentary.[207]

Tunç Şen records the following episode at the court of Bāyezīd II:[208]

> "Towards the end of Bāyezīd II's reign, one of the court astronomers (*munajjim*) approached the Sultan with a petition in Persian asking to gain access to some of the items in the treasury (*khizāne*). The requested items include a sumptuous astrolabe (*usṭurlāb-ı tāmm*), the *Zīj* of Ulugh Beg, the recension of Ptolemy's *Almagest* by Naṣīr al-Dīn Ṭūsī, and the horoscope of the Sultan and his two sons."

Alas for our purposes, no mention of any spherical astrolabe! The standard astrolabe that is mentioned is said to be تـــامّ *tāmm*, meaning "complete" rather than "sumptuous", though perhaps it was. The adjective *tāmm* in this context would mean equipped with a substantial set of plates for different latitudes.[209]

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207 On al-Kāshī see the articles by B. A. Rosenfeld in *DSB* and in *BEA* by Petra Schmidl. The manuscript is not listed in Storey, *Persian literature*, II:1, pp. 72-73 (no. 105) under al-Kāshī, but rather on p. 79 (no. 117) under an anonymous author. On the work see Kennedy, "al-Kāshī's 'Plate of conjunctions'", pp. 56-57, and *idem*, *The planetary equatorium of Jamshīd al-Kāshī*, for text, translation and commentary, esp. pp. 25 and 164 for the dedication. See also Günergun, "The Ottoman Ambassador's curiosity coffer", p. 120.

208 Şen, *Astrology in the service of the Empire*, pp. 136 and 210.

209 The spectacular astrolabe of Ibn al-Sarrāj, made in Aleppo in 729 H (1328/29) and now preserved in the Benaki Museum in Athens, which is universal in five different ways and contains five plates with some 38 different sets of markings, is referred to as تـــامّ , *tāmm* in the treatise of the 15th-century Egyptian astronomer al-Wafā'ī, who was the first of a series of owners in Cairo. For a description of this splendid instrument, the most sophisticated astrolabe ever made, see King, *In Synchrony with the Heavens*, XIVb: "Some astronomical instruments from medieval Syria", pp. 659-724, esp. pp. 694-703. A detailed analysis of the instrument and all of the relevant texts is in preparation by the author and François Charette.

Further Şen records:[210]

> "An archival register (from) ... 1505 lists ... all the items available at the time in the inner treasury. Among these listed items there are numerous quadrants (*rubʿ-i dā'ire*), several celestial globes (*hey'et topu*), at least sixteen astrolabes (large and small) preserved in velvet cases (*on altı büyük ve küçük ḳadīfe gılāf içinde usṭurlāb*), one European clock (*Frengī sāʿat*), and other sorts of astronomical instruments (*ālet-i rücūʾ-i kevākib*). Given the higher costs of owning such astronomical instruments, the status of court *munajjim* must have mitigated the problems of accessibility."

Now of interest to us are, first of all, the 16 astrolabes and numerous quadrants as well as the celestial globes, charmingly called *hay'et topu*, meaning something like "(cannon) balls of the universe". Could this last expression possibly refer to a spherical astrolabe as well as a celestial globe? One thing is certain, we will never know from this text alone. Next we turn to Şen's "other sorts of astronomical instruments". Alas, this is an over-simplified translation of the Turkish آلة رجوع الكواكب , *ālet-i rücūʾ-i kevākib*, which means "instrument for the return of the stars", and that tells us virtually nothing of consequence for it can hardly refer to an instrument for demonstrating only retrograde motion رجوع , *rujūʿ* of the planets. So what was it? It seems that we may have the answer:

There is an instrument associated with Bāyazīt II in the written sources, for which we have only its name and the name of its inventor: a Jewish astronomer Ilyās ibn Ibrāhīm al-Yahūdī (d. after 1512), known as ʿAbd al-Salām al-Muhtadà or ʿAbd al-Salām al-Daftarī after his conversion to Islam, came from al-Andalus to the court of Bayazīt II and wrote a text in Hebrew about how to use an astronomical instrument that he invented, known as الدابد (?) *al-Dābid*, a name which, if it has been correctly interpreted, makes little sense. Then he translated the text into Arabic at the Sultan's request (بتلقين السلطان , *bi-talqīn al-sulṭān*) in 1502.[211] His treatise was supposedly entitled معرفة حقيقة موضوعات الكواكب , *Maʿrifat ḥaqīqat mawḍūʿāt al-kawākib*, "(On) finding the truth about the positions

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210 Şen, *Astrology in the service of the Empire*, pp. 210-211.

211 Morrison, "Scholarly intermediary between the Ottoman Empire and Renaissance Europe", p. 36, and n. 24, citing İhsanoğlu *et al*., eds., *Ottoman astronomical literature*, I, pp. 71–73.

(?) of the stars, *i.e.*, sun, moon and planets".[212] The instrument was apparently "larger than the armillary sphere made by Ptolemy".[213]

However, there is a problem with one word in this title: "positions" would be مواضع , *mawāḍi*ʿ, plural of موضع , *mawḍi*ʿ. Also the plural of موضوع , *mawḍū*ʿ is مواضيع , *mawāḍī*ʿ or موضوعات , *mawḍū*ʿ*āt*, so the title might mean "(On) finding the truth about the subjects/topics ... ". In any case, we are clearly dealing with some kind of equatorium or orrery device showing the motions of the solar family, which would indeed show some of the planets moving backwards some of the time. It is unlikely that it would have been called آلة حقيقة موضوعات الكواكب , *ālat ḥaqīqat mawḍū*ʿ*āt al-kawākib*; rather that رجوعات , *rujū*ʿ*āt* retrograde motions, has been corrupted to موضوعات , *mawḍū*ʿ*āt* subjects. Whatever it was, the device appears to no longer be in the Topkapı today.

Finally we repeat the information on two treatises on the use of the spherical astrolabe which we mentioned above and which may well have a connection with the vibrant scene of astronomy in the time of Bāyazīt II. First, MS Istanbul Hamidiye 1453 (fols. 213v-219r, copied in 869 H (1464/65)), contains an anonymous Arabic treatise in 25 chapters (*bāb*s) on the spherical astrolabe. The treatise was either a 14th-century Syrian compilation, perhaps by Sharaf al-Dīn Mūsà al-Khalīlī, who was firmly associated with Damascus and who is known to have written on a variety of instruments, although this unique copy was executed in Edirne,[214] or it was an early Ottoman compilation, perhaps by the copyist ʿUmar ibn ʿUthmān ibn ʿUmar al-Ḥusaynī al-Dimashqī al-Asṭurlābī.[215] The author states that in his introduction that he "spent ample time learning how to make quality and beautiful instruments and finally mastered the art of globe making". Then MS Cairo Taymūr *riyāḍa* 165,4 (pp. 64-69) is the only known copy of a treatise in 20 chapters on the use of the spherical

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212 Şen, *Astrology in the service of the Empire*, p. 184, n. 51, quoting MS Istanbul Topkapı A III 3495, fol. 88a.

213 İhsanoğlu, "Science in the Ottoman Empire", pp. 212-213.

214 On Sharaf al-Dīn Mūsà al-Khalīlī see n. 37 above; and in this treatise King, "Origin of the astrolabe in the Arabic sources", pp. 57, and p. 597 of the version in *Synchrony*, vol. 2.

215 Arslan, "A Fifteenth-Century Mamluk Astronomer in the Ottoman Realm: ʿUmar al-Dimashqī and his *'ilm al-mīqāt* corpus – the Hamidiye 1453", p. 134 and n. 30.

astrolabe in Persian – *Risāla dar maʿrifat-i asṭurlāb-i kurī* – compiled by Hoja ʿAṭā'allāh ibn ʿAbdallāh al-ʿAjamī (d. 1499/1500), a scholar of Iranian origin who spent his later years in Istanbul. This part of the manuscript was copied by Muḥammad ibn Aḥmad ibn Muhḥammad al-Awsī in Medina (بلدة الرسول الاكرم , *baldat al-Rasūl al-akram*) in 992 H (1584).[216]

All we need is a copy of a treatise on the spherical astrolabe by Mūsà Jālīnūs. Until we find one, our attempt to link an instrument by Mūsà dated 1480 with a Mūsà Jālīnūs who flourished in Istanbul *ca*. 1500 will remain hypothetical.

Ottoman mathematical geography, sacred geography and qibla-indicators

The qibla or sacred direction toward the sacred Kaʿba in Mecca was of prime importance to the Ottomans not least because of their relentless construction of mosques all over the Empire. Lists of qibla directions for various cities in the Empire survive, one of them for 90 localities already published[217] and ready to be exploited to achieve insight into the orientations of major mosques.[218]

We mention here also the instruments that appear in Ottoman Turkey for finding the qibla. Although the earliest surviving Ottoman example dates from just over a century after the time when Mūsà made his spherical astrolabe, these devices combine two well-attested Islamic traditions of

(a) graphically representing the mathematically-determined qibla for specific cities on a quadrant or a circle;[219] and

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216 *Ibid*., p. 134, n. 30, and İhsanoğlu *et al*., *Ottoman astronomical literature*, I, pp. 66-67, also, on the manuscript King, *Cairo Survey*, no. G97 (*ad* I, pp. 597-598, and II, §4.2.5, of the Arabic catalogue)..

217 King, "Ottoman qibla list", previously published in *idem*, *World-Maps for finding the direction to Mecca*, pp. 86-87 and 622.

218 Yilmaz & Tiryakioglu, "The astronomical orientation of the historical Grand Mosques in Anatolia" (2018).

219 Such qibla directions for various localities are shown on two instruments from 12th-century Isfahan and 14th-century Damascus illustrated in King, *Synchrony*, XIIIa: 371 and I: 96.

(b) dividing the whole world into sectors about the perimeter of the astronomically-oriented Kaʿba so that the regions in each sector face a qibla determined by tradition.[220]

I have not located an early Ottoman geographical table or device serving the former function. But there is a selection of Ottoman schemes of sacred geography with different numbers of sectors arranged around the Kaʿba which have inspired the circular Ottoman qibla-indicators *cum* sundials such as the one signed by Bayrām ibn Ilyās and dated 990 H (1582/83) in the British Museum.[221] This has some three localities in each of 72 divisions about the Kaʿba at the centre. The name قسطنطنية, Qusṭanṭiniyya (Constantinople) alone is highlighted in red ink, indicating the maker's location. To what extent any kind of instrument was used in practice is not made any clearer by the curious array of orientations of early Turkish mosques.

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220 Details are given in King, "Some Ottoman schemes of sacred geography" (1986). On qibla-indicators in general see King, *World-Maps*, pp. 107-123, especially pp. 116-117 on two Ottoman examples. See Appendix 1a for an Ottoman qibla-indicator that is not functional.

221 A recent article on this instrument by Meghan Doyle is not an "in-depth study" as the author claims but a series of fanciful modernistic interpretations of a single historical object, one out of several available, considered out of context. As such it is in line with much modern scholarship by non-specialists dealing with complicated historical objects.

A prime example of this new trend is Bentley, "Art, science and mathematics in an astrolabe from 14th century Spain" (2018), where the delicate story of the most important singular astrolabe from 14th-century Toledo, with inscriptions in Hebrew first, then Latin and then Arabic, is related 'backwards' (with Hebrew last) and hence totally misrepresented. But even these pale when compared with Armienti & Venger, "A Middle Age Qibla finder and the secret code of Portolan maps" (2017), dealing with an object which has no Arabic inscriptions and is not Islamic anyway, and has nothing to do either with the *qibla* or with portolan maps. I have a similar object hanging on the wall of my late medieval farmhouse in the Ardèche; it is rectangular and I have wondered whether it might represent the world-map of the 9th-century Caliph al-Ma'mūn of Baghdad, which map we know was rectangular with an orthogonal grid even though some have claimed it was spherical.

8 The remarkable written heritage of Mūsà Jālīnūs

The writings of Mūsà Jālīnūs have been studied for the first time, mainly over the past 10 years, by Juan Vernet, Julio Samsó and María José Parra (the canons to Zacuto's auxiliary tables for calculating ephemerides), Tzvi Langermann (the Hebrew treatise on "puzzles"), and Robert Morrison (the Arabic treatise on theoretical astronomy as well as the Turkish treatise on compound medicines). This author is pleased to have been involved at least in the first undertaking.

Tzvi Langermann has written:[222]

> "Galeano's special interest in astronomical instruments would have served him well at the court of Bayazid II. The Sultan himself studied astronomy with Mīram Chelebī, grandson of the famous Qādīzadeh, and several astronomers dedicated treatises, mostly on instruments, to Bayazid II."

This is therefore the right time to enquire whether any instruments by him survive, and fortunately we have at least one.

Theoretical astronomy: geometrical models for the sun, moon and planets

In Istanbul *ca*. 1500 Mūsà Jālīnūs الطبيب , al-Ṭabīb "the medic" wrote a short but significant work on theoretical astronomy **in Arabic.** This is extant in MS Istanbul Topkapı AIII 3302/2 (fols. 101-107, copied in the early 16th century).[223] It has been investigated in a masterly fashion by Robert Morrison.[224] Mūsà was familiar with developments in this topic that had influenced Islamic theoretical astronomy, not least with the astronomical models of the 14th-century Damascus astronomer Ibn al-

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222 Langermann, "Compendium of Renaissance science", p. 288.

223 The manuscript is first mentioned in Krause, "Stambuler Handschriften", p. 520, and I inspected it in the 1970s, noting that it merited detailed study (*Cairo Survey*, no. H3).

224 See now Morrison, "An astronomical treatise by Musa Jalinus" (2011), and *idem*, "A scholarly intermediary between the Ottoman Empire and Renaissance Europe" (2014).

Shāṭir.[225] He was also familiar with the tradition usually associated with certain Andalusī astronomers with a philosophical inclination who opposed Ptolemaic theoretical astronomy and favoured an approach that rejected both Ptolemy's epicycles and eccentrics.

Morrison has shown how Mūsà's description of his solar model is borrowed from the astronomical treatise in Judaeo-Arabic by the Jewish scholar Joseph ben Naḥmias, compiled somewhere in the Iberian Peninsula *ca*. 1400, a work which probably became known in Istanbul *ca*. 1500 as a result of the Sephardic diaspora.[226]

We know that Mūsà visited Venice and Padua between 1497 and 1502, and that he was familiar with the planetary astronomy of Ibn al-Shāṭir as well as the contemporaneous Amico, and Fracastoro of Padua. Copernicus also spent time in Padua (1501-03).

Since the 1950s scholars have been searching for a supposed link between the geometric models proposed by Muslim scholars such as Naṣīr al-Dīn al-Ṭūsī and Ibn al-Shāṭir and those of Copernicus. Research on the Arabic and Persian manuscripts in the Vatican Library and elsewhere has so far failed to find a 'missing link'. The only known Hebrew version of the *Zīj* of Ibn al-Shāṭir is anonymous; it was discovered by Bernard R. Goldstein in the 1970s, but the manuscript is from 19th-century Aleppo.[227] Again, it would be very interesting to know whether this or any other Hebrew version was available in Istanbul four centuries earlier. Now, at the same time that Robert Morrison has found a possible link through a Jewish astronomer familiar with Ibn al-Shāṭir's work, who travelled from Istanbul to Venice and Padua, we also have a modern mathematician Viktor Blåsjö, who claims that there is no connection between the models of the Syrian

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225 See my articles "Ibn al-Shāṭir" in *DSB* and *BEA*, and on his planetary theory see Kennedy e*t al*., *Studies*. See also Saliba, *Islamic Science and the making of the European Renaissance*, *passim*, and the references there cited.

226 Morrison, *The Light of the World,* pp. 41-42.

227 Goldstein, "The survival of Arabic astronomy in Hebrew", foot of p. 38.

astronomer and the Polish astronomer.[228] This is not the place for further comment on this situation, but the reactions of the specialists are awaited with interest! The bibliographical situation, including a mention of Mūsà Jālīnūs, is outlined in a 2018 study by Kevin Krisciunas and Belén Bistué.[229]

Life's puzzles

Mūsà's work **in Hebrew** entitled תעלמות חכמה , *Ta'alumot hokmah*, "Puzzles of wisdom", was apparently written *ca*. 1500. In 1536 Mūsà himself added comments to the unique MS Cambridge University Library Add 511,1 when he was in Candia, that is, Crete, which he calls "the place of wandering". The main text had been copied by his student, Abraham Algazi. Some sections have been added and others annotated, while one was crossed out by the author. Parts of this work have been studied in depth in a brilliant fashion by Tzvi Langermann,[230] who regards it as:

> "one of the most idiosyncratic and historically interesting specimens of Hebrew scientific literature".

Even judging by the extracts presented and analyzed by Langermann, this is a truly most unusual document, with a strong philosophical and ethical bent. To quote my colleague further:

> "the work is organized in ten sections, which the author labels *ḥadarim* ('chambers'), each section groups together examples of similar errors of reasoning from different fields of knowledge: religion (including law, interpretations of scripture, and polemics), mechanics (or 'machinations'), medicine, astronomy, and astrology. Generally, Galeano begins each 'chamber' with an explanation in logical terms of the error involved; this 'fallacy' is then the organizing principle of the chapter."

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[228] Blåsjö, "A critique of the arguments for Maragha influence on Copernicus" (2014). I thank Prof. Jan Hogendijk for sending me this article in March, 2018, after I had given a lecture in Frankfurt (IGAIW), in which I mentioned the Ibn al-Shāṭir-Copernicus connection. I have never worked on Islamic theoretical astronomy myself.

[229] Krisciunas & Bistué, "Where did Copernicus obtain the tools to build his heliocentric model?".

[230] Langermann, "A Compendium of Renaissance Science: *Taʿalumot hokma* by Moshe Galeano" (2007).

Langermann's second study of Moshe's treatise presents materials which are guaranteed to astonish any reader familiar with medieval scientific literature.[231] Let us consider here simply his section headings on medical matters: two cases of medical intrigue at Court; a dentist's sleight of hand; a bloodletting controversy; two applications of medical astrology; pure and simple medical fraud; a tragic case of amateur treatment. Then on magical matters: weather forecasting; exposing spell-casters. Furthermore we now learn that Moshe, who was very interested in mechanical devices, actually built a robot! Made of wood and in the form of a human with a gown reaching the ground, this could move across a room at the command of its 'controller'. Mūsà constructed such a device to impress "the military commander of the king of the Turks".

Explanatory text (canons) to the solar, lunar and planetary tables of Zacuto

By the time Mūsà returned from Italy to Istanbul, he knew enough Latin to translate into Arabic the Latin version of the canons (instructions) of the *Almanacum perpetuum* of Abraham Zacuto (זכות or زكوط) of Salamanca (a work composed originally in Hebrew, then translated by others into Castilian and then Latin).[232] This Arabic version was completed in 912 H (1506/07). Mūsà was commissioned to prepare it the previous Hijra year by ʿAbd al-Raḥmān Mu'ayyad Zāde, قاضي العسكر , *qāḍi 'l-ʿaskar*, the judge of the Ottoman military, who had received part of his education in Shiraz, notably in philosophy, and who died in 922 H (1516).[233] He states that some of the tables can only be used at the latitude of 41°30′,[234] which was one of the values then used by serious astronomers for Istanbul and which had perhaps recently been re-measured after its capture by the Ottomans in

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231 Langermann, "Medicine, mechanics, and magic from Moses ben Judah Galeano's *Taʿalumot hokma*" (2009).

232 On Zacuto and his work see Chabás & Goldstein, *Astronomy in the Iberian Peninsula: Abraham Zacut*, and on these canons see pp. 163-164 (where the author is confused with Moses ben Elijah Galina).

233 # See also n. 246 below.

234 Samsó, "Zacut in Arabic", pp. 83 and 95, n. 3; *idem*, "Zacut in the Eastern Islamic world", p. 68; and Chabás & Goldstein, *Astronomy in the Iberian Peninsula: Abraham Zacut*, pp. 170-171.

1453.[235] (It should be borne in mind that some hapless Byzantine astronomers had taken the latitude as 45°, presumably situating their capital in the 6th of the seven Ptolemaic climates rather than the 5th.[236])

Hebrew translations of Arabic treatises on instruments

Thanks to the painstaking researches of Moritz Steinschneider and his 1893 book on the role of Jews as translators in the Middle Ages, it has long been known that Mūsà Jālīnūs was interested in instruments.[237] In particular, he translated **from Arabic into Hebrew** a work on the sine quadrant רסאלה אלעמל באלרבע אלמגיב from رسالة العمل بالربع المجيب , simply "A treatise on the use of the sine quadrant", by one Muḥammad ibn Muḥammad. If this is a special kind of trigonometric quadrant بلا مري , *bi-lā murī*, that is, without a bead on the thread attached to the centre and without the semi-circle for finding sines and cosines with facility, then we are probably dealing with an interesting treatise by the outstanding Damascus astronomer Shams al-Dīn Muḥammad ibn Muḥammad al-Khalīlī (*fl. ca*. 1360).[238] The far more prolific but far less impressive Cairo astronomer Sibṭ al-Māridīnī (d. 1506/07),[239] author of a plethora of treatises on quadrants and sundials, has also been proposed as the author of the original Arabic treatise.[240]

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235 King, "Astronomical timekeeping in Ottoman Turkey", and *idem*, *In Synchrony with the Heavens*, I:14 "Turkish tables for timekeeping".

236 King, "Notes on Byzantine astronomy", pp. 117-118.

237 Steinschneider, *Die hebräischen Übersetzungen des Mittelalters und die Juden als Dolmetscher*, pp. 575-577.

238 # On Shams al-Dīn al-Khalīlī see the references in n. 32 above. The information from Steinschneider is cited in my 1975 study "al-Khalīlī's qibla table", p. 108, n. 28.

239 Suter, *Mathematiker und Astronomen*, no. 445, and King, *Cairo Survey*, no. C97. See King, "al-Khalīlī's qibla table", esp. pp. 111-115, where a complicated procedure described by Sibt al-MāriDīnī is explained.

240 For example, İhsanoğlu *et al*., *Ottoman astronomical literature*, I, p. 224, and *idem*, "Scholars of Andalusian origin ... ", pp. 20-21.

In addition, Mūsà translated into Hebrew a commentary by one Aḥmad ibn Aḥmad al-Sunbāṭī (d. 1582 or 1589)[241] on a treatise known as الـفتحية *al-Fatḥiyya* on the standard trigonometric quadrant by Sibṭ al-Māridīnī. This commentary must have been written when al-Sunbāṭī was quite young, and the translation when Mūsà was well advanced in years.[242] Having seen several copies of al-Sunbāṭī's commentary it is difficult to imagine why Mūsà thought it was worth translating.

Another work by Mūsà documented by Steinschneider was a Hebrew translation of an anonymous 6-page Arabic treatise on the صـفيحة , צפיחה , *ṣafīḥa* (either the universal plate or the celestial coordinate converter) of Ibn al-Zarqāllu (Toledo, *ca*. 1100).[243] The Hebrew or Judaeo-Arabic treatises listed by Steinschneider are extant in manuscripts preserved in Berlin which apparently have not been studied since his time over a century ago.

When writing about the apparent daily rotation of the heavens,[244] Mūsà states:

> " ... the heavenly bodies, and every heavenly motion, trace equal arcs on their orbs in equal times. This is true, even though we observe with our instruments that it is not so."

It is not for this author to comment on such a remarkable statement, save to suggest that the reference to "our instruments" is probably meant generally rather than specifically to himself, or his own instruments.

A treatise on compound medicines

Mūsà Jālīnūs الإسرائيلي , al-Isrā'īlī, فقير أصغر الأطباء , "the most wretched of medics", also wrote a medical treatise in **Ottoman Turkish** commissioned by Bāyazīt II's chief medic رئيس الحكماء , *ra'īs al-ḥukamā'* Ahi Çelebi, who assumed office in 1507 and was also interested in astronomy. The Arabic

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241 On this author see Suter, *Mathematiker und Astronomen*, no. 470, listing six manuscripts and quoting a Berlin MS stating that he died in 990 H (1582); King, *Cairo Survey*, no. C126, listing nine Cairo manuscripts; and İhsanoğlu *et al*., *Ottoman astronomical literature*, no. 98, listing over 30 manuscripts.

242 Langermann, "Compendium of Renaissance science", p. 288 and n. 5 on p. 289.

243 # See n. 79 above.

244 Langermann, "Compendium of Renaissance science:", p. 291.

title reads of this treatise reads رسالة في طبائع الادوية واستعمالها , *Risāla fi Ṭabā'iʿ al-adwiya wa-'stiʿmālihā*, "Treatise on the natures of medicines and their use". The only known surviving copy is MS Istanbul University Yıldız Tip 352.[245] The text of this remarkable treatise, assembled, according the author, "from the words of Islamic, Frankish, Greek, and Jewish physicians", was published with English translation and commentary by Robert Morrison in 2016.[246] Mūsà refers to another medical work of his **in Hebrew**, ספר השראשים , *Sefer ha-Sorasim*, "Book of principles", in which he treats "my medical problems".[247] In addition, he wrote some treatises in **Hebrew** on logic which still await study.[248]

Trade with manuscripts

Robert Morrison has documented the activities of Mūsà Jālīnūs / Moshe Galeano within a group of scholars who transmitted texts between Candia, that is, Crete (then part of the Venetian Empire), the Ottoman Empire, Italy and points north. It appears that he was part of a network of Jewish scholars in Candia, with connections to Istanbul, that sold Hebrew manuscripts in the early 1540s to the Christian humanist banker Jakob Fugger (d. 1525) of Augsburg and his family.[249] The potential historical importance of this mode of transmission of knowledge from the Ottoman Empire to Europe is not to be underestimated.

Excursus: Where did Mūsà come from?

Mūsà Jālīnūs may seem to appear in Istanbul out of nowhere, but we do have one important clue to his provenance. This is in the unique Escorial

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245 İhsanoğlu *et al.*, *Ottoman medical literature*, I, 108-9 and 135, attributes this work to Mūsà ibn Hāmūn al-Isrā'īlī but the father's name is not given in the Istanbul manuscript.

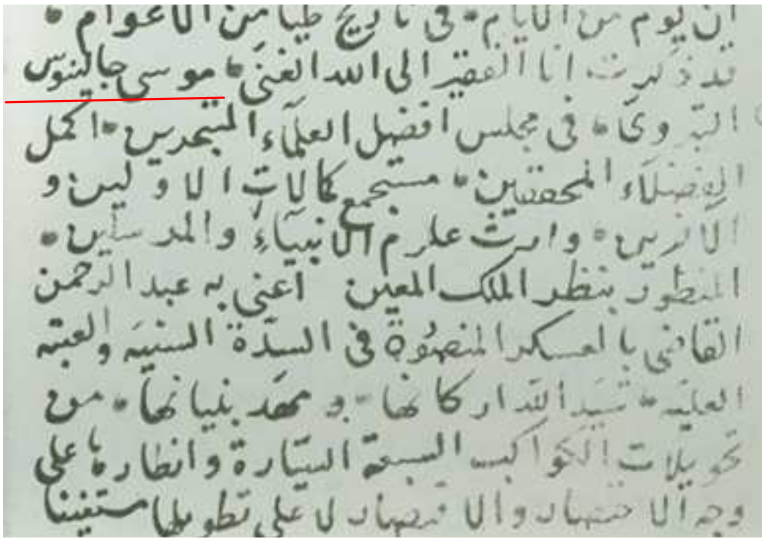
246 Morrison, "Musa Calınus' Treatise on the natures of medicines and their use". Ahi Çelebi was also known as Muhammad ibn Kamāl al-Tabrīzī (*ibid*., p. 78, n. 4).

247 Morrison, "Astronomical treatise by Musa Jalinus", p. 345.

248 Langermann, "Compendium", p. 285.

249 Morrison, "A scholarly intermediary between the Ottoman Empire and Renaissance Europe", pp. 54-56, mentioning several surviving manuscripts.

Library manuscript of his Arabic canons to Zacuto's *Almanach*,[250] which is of Egyptian provenance and is copied in a careful *naskhī* hand datable to shortly after 1500. Here the author's name appears as Mūsà Jālīnūs التبروي , *al-T-b-r-w-y* – see the extract from the Escorial manuscript. (The epithet is given by his editors Juan Vernet and María José Parra as اليتروي , *al-Yatrawī* from *al-Y-t-r-w-y*.[251]) This is an Arabic name indicating his place of origin, or at least that of his family.


اي يوم من الايام • في تاريخ طلبا من الاعوام •
فقد ذكرت انا الفقير الى الله الغني • موسى جالينوس
التبروي • في مجلس افضيل العلماء المتبحرين • اكمل
الفضلاء المحققين • مستجمع كمالات الاولين و
الاخرين • وارث علوم الانبياء والمرسلين •
المنطوق بنظر الملك المعين اعني به عبد الرحمن
القاضي بالعسكر المنصورة في السدة السنية والعتبة
العلية • شيد الله اركانها • وممهد بنيانها • مع
تحويلات الكواكب السبعة السيارة وانظارها على
وجه الاختصار والاقتصار لا على تطويلها مستغنيا

An extract from the unique copy of Mūsà Jālīnūs' Arabic introduction to his version of the perpetual almanac of Zacuto. From MS El Escorial árabe 966, fol. 1v, with thanks to Dr. María José Parra.

Neither التبروي , *al-T-b-r-w-y* nor اليتروي , *al-Y-t-r-w-y* can be correct. However, both clearly derive from an adjective *al-*-*-#-awī* where *

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250 I thank Dr. María José Parra Pérez for sending me a copy of a paper she delivered at Cambridge in 2002, in which the relevant folio is illustrated.

251 Vernet, "Una versión árabe resumida del almanach perpetuum de Zacuto" (1950), p. 115, and Parra Pérez, *Traducciones al árabe del* Almanach perpetuum *de Zacuto*, pp. 18-19, 37-42, 279-304, esp. p. 281 for the epithet al-Yatrawī (read as 'Alitreu' by the 18th-century Arabist Casiri – Vernet, p. 118).

stands for *b/t/th/n/y* and # stands for *r/z* and both would indicate an Arabic place-name ending in *-a(h)*, *ā* or *ā'*. Nothing immediately comes to mind, even with the help of atlases of the Ottoman world and beyond.[252] The name al-Batrā', the modern Arabic name for the ancient Nabatean site of Petra in Jordan, could conceivably yield البتراوي , al-Batrāwî or البتراني , al-Batrānī or البتروي , al-Batrawī, but nobody came from there in those days.[253] There was an Ottoman town called Nyitra in what is now Hungary, but it would seem most improbable.[254]

Now there is a town some 70 km south-east of Izmir called Tīre in Ottoman Turkish (written تيره , *T-y-r-h*), modern Tire.[255] In classical times it was known as Arcadiopolis, later Teira. In the Byzantine period it was called Thyrea and Thyraia. It featured a mint down to the 16th century. The famous Maghribī traveller Ibn Baṭṭūṭa visited Tīre around 1330 and found the town "in the midst of orchards, gardens and streams". In 1426 after the Ottoman annexation of the principality of the Aydınoğlu the town became capital of a *sanjaq* or administrative region of the Empire. Several Ottoman scholars came from Tīre: the *Encyclopedia of Islam* mentions three but implies the existence of more. May we perhaps add a fourth?

Certainly al-Tīrawī (written التيروي , *al-T-y-r-w-y* and meaning from Tīre) and al-Yatrawī (written اليتروي , *al-Y-t-r-w-y* but meaningless) and al-Batrawī (written البتروي // *al-B-t-r-w-y*, also meaningless) can be easily confused in Arabic (because initial and medial *y* and *t* are the same basic shape in Arabic, as are *y* and *b*, differing only in the dots, which in manuscripts are often omitted or confused anyway).

Although the Jews in nearby Smyrna (Ismyrna, Izmir) were all murdered by the Byzantines shortly before the Ottoman conquest in the mid-15th

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252 Pitcher, *An historical geography of the Ottoman Empire*, is still useful.

253 Not even the first Muslims! See King, "From Petra back to Mecca".

254 This situation reminds one of the Turkish scholar from Yanina (Greek Ioannina in Epiros) called Asʿad Efendī اليانيوي al-Yāniyawī (d. 1730), a name that, because of the -*-*-*- for *-y-n-y-* combination, has caused confusion and distortions in some modern writings. On this scholar and his works see King, *Cairo Survey*, no. H30; Rosenfeld & İhsanoğlu, *Mathematicians and astronomers of Islamic civilisation*, no. 1327; İhsanoğlu *et al.*, *Ottoman mathematical literature*, no. 111 (also no. 113); and also Berggren, "Archimedes among the Ottomans", pp. 101-109.

255 The information in this paragraph is taken from the article "Tīre" by Franz Babinger in the *Encyclopedia of Islam*, 2nd (from 1st) edn.

century, Tire continued to have a substantial Jewish community in Ottoman times.[256] The mint would have been run by Jews, as were Ottoman mints in general.[257] This author believes all evidence points to Tire as the place we can safely associate with Mūsà before he came to Istanbul. On the other hand, if التبروي , *al-T-b-r-w-y* in the Escorial manuscript results from a really careless scribal error (or, more likely, a chain of careless errors) for اليهودي , *al-Yahūdī,* "the Jew", which is not inconceivable, then this may be altogether wrong and the discussion should in that case be suppressed. On the other hand, the Escorial manuscript was copied not long after Mūsà prepared the Arabic version of the canons.

It is not without interest that the Turkish historian of science Aydın Sayılı in his splendid book *The Observatory in Islam* (1960) mentions a local tradition in Tire, recorded in a pamphlet dated 1935, that there was an "observatory" attached to the Yavukluoğlu Mosque in the town.[258] This, as Sayılı realized, was most probably a موقتخانه , *muvakkithane*, a room or set of rooms used by astronomers associated with the mosque.[259]

Excursus: Some Jewish astronomers of late-15th-century Istanbul

The Byzantine city of Constantinople, following the murderous Fourth Crusade of 1204, enjoyed renewed progress and reconstruction under the Palaiologan dynasty (1261-1453). This was interrupted substantially when Meḥmet "the Conqueror" gained control over the city in 1453. To revive the city the Sultan ordered that Muslims, Christians and Jews from all over

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256 Gary Mokotoff in *Avotaynu: The International Review of Jewish Genealogy* 14 (1998), p. 40, writing on the basis of a survey of 60,000 Ottoman tomb-stones from Western Anatolia. See also www.jewsoftire.com on more recent Jewish inhabitants in Tire.

257 Shaw, *The Jews of the Ottoman Empire*, p. 87.

258 Sayılı, *The Observatory in Islam*, p. 247, citing a document entitled *L'Administration de l'Evkaf à la V. Foire International du 9 septembre à Izmir, Arts et cultures, urbanisme, tourisme*, Izmir: Marifet Press, 1935.

259 On buildings of this type in Istanbul see Ünver, "Osmanli Türklerinde ılim tarihinde muvakkithaneler"; and Aydüz, "İstanbul muvakkithaneleri ve muvakkitleri", both richly illustrated. What the *muwaqqit*s did in this buildings, as far as their tables were concerned, is related in King, "Astronomical timekeeping in Ottoman Turkey".

the Ottoman Empire be resettled in his new capital. Within months most of the Empire's Romaniote Jews from the Balkans and Anatolia were concentrated in Istanbul, where they made up 10% of the city's population (according to Avigdor Levy). The Romaniotes would be the most influential of all communities in the Ottoman Empire for some decades to come. The greatest influx of Jews into Asia Minor and the Ottoman Empire, occurred during the reign of Meḥmet II's successor, Bāyezīt II (1481–1512) after their expulsion from the Iberian Peninsula, Southern Italy and Sicily, when the Sultan allowed Jews expelled from Spain and Portugal to settle in the Ottoman Empire, and they started arriving in great numbers.

Jews in the Ottoman Empire were especially good as iron forgers, smiths, wheelwrights, coach builders, sail makers, and rope makers. Some were expert sailors and fishermen. There were also Jewish painters, shoemakers, hide processors, workers in precious metals such as gold and silver, locksmiths, lime burners, masons and the like in all the major Ottoman cities.[260] But it is the Jewish scholars with serious interest in astronomy who are our concern here rather than craftsmen, though in medieval times it was possible for an astronomer, and a 'publishing one' at that, himself to make an astronomical instrument. We have already mentioned the early-10th-century Baghdad astronomers Ḥāmid al-Wāsiṭī and Nasṭūlus, who wrote treatises and made first-class instruments. Likewise Ibn al-Shāṭir, the leading astronomer of the 14th century and a prolific author, made astronomical clocks, astrolabes, sundials and compendia.

Our Mūsà states that he studied under **R**abbi **E**lijah ben Abraham **M**izraḥi (1437-1526), generally known by the Hebrew acronym ראֵ״ם **Re**ʾe**m**, who was one of the greatest rabbis of the Romaniote community of Istanbul. Born there around the middle of the 15th century, he headed a *yeshiva* and apparently figured as the leader of the city's rabbinical community. Aside from being an adjudicator of Jewish law, Mizraḥi possessed broad general knowledge on numerous subjects. He produced a substantial body of works on medicine, mathematics, astronomy, geography, the Talmud and Jewish law, before he became preoccupied with administrative positions. Tzvi Langermann kindly informs me that Mizraḥi wrote a long commentary on Ptolemy's *Almagest*, the only one he knows where the author consulted Ptolemy's text in three languages: Hebrew, Greek, and

260 Shaw, *The Jews of the Ottoman Empire*, p. 92.

Arabic.[261] Not only is this a remarkable feat in itself, but Mizraḥi appears to be the only non-Greek scholar in Istanbul at the time who confronted this monument of ancient (and medieval) astronomy. He became the head of a Romaniote synagogue in Istanbul in 1475, subsequently being appointed second Grand Rabbi of the Ottoman Empire in 1495 following the death of its first occupant, Moshe Capsali.[262]

On the subject of the *Almagest*, the Greek scholar George Amirutzes (b. Trebizond, date?, d. Istanbul, 1475), a correspondent of Bessarion, had close contacts to Sultan Meḥmet II. Amirutzes supported the Sultan's cultural policy, which included proposed new translations of the Almagest into Arabic and Turkish (that were never undertaken).[263]

Another Jewish scholar in these early years of Ottoman rule who had an interest in astronomy was Mordechai ben Eliezer Comtino (1402-1482). He undertook making accessible to the masses basic knowledge in logic, philosophy, mathematics, and the natural sciences. His ספר החשבון והמדות , *Sefer ha-Ḥeshbon ve ha-Middot*, "Book of reckoning and measurements", taught the basics of arithmetic and geometry. His פירוש לוחות פרש , *Perush Luḥot Paras* was a "Commentary on Persian astronomical tables".[264] His תיקון כלי הצפיחה , *Tikkun Keli ha-Zefihah* is mentioned in the literature as a work on the construction of a sundial but was more likely a work on the صفيحة , צפיחה , *ṣafīḥa* or universal plate associated with Ibn al-Zarqālluh. Another work of Comtino's, was ספר התכונה , *Sefer ha-Tekunah*, "Book on astronomy".[265]

A certain Elia Bashyaṣi, who died in Istanbul in 1490, mentioned Ulugh Beg's tables in his work on astronomy and the Karaite calendar published in Istanbul in 1530/31, and in a supplement to a Jewish prayer-book

261 Email of 12.06.2018. It is a pleasure to thank Tzvi Langermann for this and other useful exchanges over many years.

262 Distilled from Shaw, *Jews of the Ottoman World*, p. 101, and Yaron Bean Naeh, "Mizrahi, Elijah ben Abraham", in Stillman, ed., *Encyclopedia of Jews in the Islamic world* (accessed 2018)..

263 King, *Astrolabes and angels*, p. 27.

264 Also Morrison, "A scholarly intermediary between the Ottoman Empire and Renaissance Europe", p. 37.

265 Shaw, *Jews of the Ottoman Empire*, pp. 101-102, and article "Comtino ... " by Yaron Ayalon in Stillman, ed., *Encyclopedia* (accessed 2018).

published in Venice in 1520 we learn that R. Abraham ben Yom Tov Yerushalmi, known to have been in Istanbul in 1510, used the tables of Ulugh Beg.[266]

These notes make no pretension of completeness, but the author is reminded of the flurry of activity amongst Jewish astronomers in Sicily (late 14th to late 15th century) relating to different varieties of serious astronomical instruments of the non-standard variety.[267] One should also note that instrument-making continued in Istanbul for several centuries thereafter; most of the relatively few surviving Ottoman examples, which tend to be rather staid and simple (like Maghribī instruments, but unlike Persian instruments), have been catalogued.[268]

266 Goldstein, "The survival of Arabic astronomy in Hebrew", pp. 38-39.

267 See Goldstein, "Description of astronomical instruments in Hebrew".

268 King, *Catalogue of Medieval Islamic Instruments*, Section 2.3 on late Ottoman astrolabes after *ca*. 1500.

9 The ‘new’ spherical astrolabe of al-Zaʿīm

None of this section is relevant to the main topic of this study. It is included it here only because quite some time and effort was spent preparing it.

Provenance

A third spherical astrolabe with Arabic inscriptions surfaced in a European private collection a few years ago. According to the owner, this instrument was formerly in the possession of the Ben Ghazi family of Fez, some members of which had been *muwaqqit*s (astronomers responsible for the times of prayer) and muezzins (officials who announce the call to prayer) at the celebrated al-Qarawiyyīn Mosque there.[269] The instrument ‘must have been’ brought to Fez at some time in the past, for it is certainly not of Maghribi origin. This statement about the provenance of the piece is to be taken with a grain of salt.

From the appearance of this new previously-undocumented spherical astrolabe[270] one might suppose that it stems from the same Istanbul workshop as the other surviving complete spherical astrolabe preserved in Oxford. That one, as we have seen, is signed simply “Mūsà” and it was made in 1480/81. Therefore, perhaps the ‘new’ instrument can be similarly dated. However, the ‘new’ instrument is signed even more enigmatically

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269 See Nasr, *Islamic science – An illustrated study*, 117, pl. 70, for an image of a muezzin in Fez reading the time from a sundial at the Qarawiyyīn Mosque in the 1970s. Note that he is wearing a watch.

270 # In mid June 2018 an undated 2-page anonymous report on the instrument was brought to my attention. This was clearly prepared by someone familiar with the history of Islamic instrumentation though not an Arabist (which really limits the possibilities!), The author was in fact the late London Islamic art expert, Oliver Hoare, who correctly observed that:

> “The two instruments (MUSA & ZAIM) are clearly closely related and must have been made in the same workshop, if not by the same instrument maker, although there are significant differences in the details of their manufacture.”

However, the instrument was incorrectly deemed to be from Fez, *ca*. 1480; the maker’s name was misread as ‘al-Zaʿini’; the star-names were not interpreted and the star-positions were not investigated; and a decoration on the throne was deemed to have served as a *qibla*-indicator (see n. 230). See further [Hoare], “A highly important spherical astrolabe”.

"al-Zaʿīm", which is perhaps a rather surprising name for a medieval Muslim, but by no means an impossible one.

The engraving on MUSA and ZAIM is apparently very similar, in many ways close to identical, although a microscopic comparison has not been conducted. We shall consider several differences and peculiarities below.

It is clearly not possible to consider the new spherical astrolabe ZAIM in isolation from Oxford's MUSA. If no other examples were known, this new piece would probably be met with extreme scepticism by those of us concerned with medieval Islamic instruments, few as we are in number.

Dimensions and weight

The diameter of the sphere is 9.98 cm; the thickness of the rete is 2 mm; the total height with throne and ring extended is 14.5 cm. The total weight of the instrument is 1379.4 grams. The sphere alone weights 1151.9 grams. The rete alone weights 225.9 grams. The silver pins together weigh 16 grams.

The sphere is hollow but apparently cast as one single piece with no visible seam or 'plug', although there two very curious 'bald spots' at the two poles of the sphere. (The sphere is thus different from the sphere of Oxford's spherical astrolabe MUSA, which is hollow and made up for two much lighter halves that can be unscrewed and separated.)

Where did the sphere come from?

Although both the MUSA and ZAIM instruments are hollow, ZAIM is composed of a thick metal crust. Its weight of 1.15 kg compares with that of small Ottoman cannon-balls (*top güllesi*), which could weigh 0.9, 1.3 or 1.5 kg, although their diameters are not clearly indicated.[271] Only a metallurgical investigation might determine whether our spherical astrolabe started life in this way. Or perhaps an X-ray? See further below.

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271 Gábor Ágoston, article "Top [= cannon]" in *İslâm Ansiklopedisi,* vol. 41 (2012), pp. 240-242, esp. p. 242.

On taking x-rays of cannon-balls see the discussion in www.americancivilwarforum.com/can-a-cannonball-be-x-rayed-to-determine-if-it-is-solid-or-hollow-207302.html (accessed 2018).

The signature

There is a ‘signature’ inside the ecliptic ring on the rete (see below) which states عمل الزعيم , *ʿamal al-Zaʿīm*, “made by al-Zaʿīm”. This is in an elegant and quite distinctive script. In the first word, the final لــل , *lām* is engraved backwards under the initial عــعع , *ʿayn* and medial مــمم , *mīm* and ending attached to the bottom of the medial مـمم , *mīm.* In the second word, the tail of the final مــمم , *mīm* goes up and down in a small ‘hump’ and then up and around and backwards to just above the ز , *zāy*. The script of this rather clever inscription is certainly different from that on the outside of the rete, and it would not have been a simple task to engrave it inside the rete, on a curved band of metal some 9 mm wide. The word *zaʿīm* means “chief” or “boss” in modern Arabic, but it is used in the *Qur’ān* and has a most interesting history in medieval Arabic – see Appendix 2.

The remarkable signature on the ‘new’ spherical astrolabe. Not only is engraving most unusual, with its backward letter and its curious ligatures, but the name itself is guaranteed to amuse modern Arabic-speakers and confuse medieval Arabists. Note also the indentations of the degree scale on the ecliptic ring.

It was usual for the makers of astronomical instruments in the Islamic world to sign their instruments visibly and with their full names. One could assume that a craftsman who signed himself with simply a given name must have been well-known in his milieu.[272] But it is not unknown for even a highly-competent craftsman to ‘sign’ his work in such a way that his signature is not visible or not even registered.[273] We return to the name al-Zaʿīm in Appendix 2.

Markings on the sphere

The markings on the sphere are divided between the two hemispheres bounded by a circumference that is neither clearly marked nor labelled. This is the horizon. Below it there is a scale marked and labelled for each 5°, rather crudely subdivided into single degrees. The meridian is perpendicular to the horizon and can be identified by the words الشمال , *al-shamāl* and الجنوب , *al-janūb*, north and south, below the horizon. The divisions of each 5° are labelled in each quadrant, sometimes forwards sometimes backwards. The actual letters representing the numbers are written backwards, as on MUSA.

The altitude circles are primarily for each 5° of altitude, with additional circles between these at 1°, 2° or 3° somewhat haphazardly situated. Sometimes one finds circles at 1° or 4° between the principal ones. The arrangement can only be described as bizarre. It lacks all of the initiative and success of the markings on Oxford’s MUSA. (Note that on the TUNIS spherical astrolabe the problem is addressed and solved by having altitude circles for each 10° only.)

At azimuths 20° E of N and 20° W of S there are two altitude scales marked and labelled for each 5° of altitude. The choice of these directions seems arbitrary. At azimuths 20° N of W and 20° S of E there are also

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272 See Mayer, *Islamic astrolabists*, for a list of all makers of astrolabes known in the 1950s, and Savage-Smith, *Islamicate celestial globes*, pp. 334-335, for all known makers of globes known *ca*. 1980. The table of contents of my (incomplete) *Catalogue of medieval Islamic astronomical instruments* shows makers organized chronologically by region.

273 A good example is the replacement rete of the magnificent 13th-century Syrian astrolabe of ʿAbd al-Karīm al-Miṣrī preserved in Oxford. The date of completion of the replacement rete is engraved on the back of the rete; the maker is not named but is clearly Jalāl al-Kirmānī, the leading instrument-maker of Samarqand in the early 15th century. On the instrument in question see Gunther, *Astrolabes of the World*, I, pp. 121 (no. 7) on the rete, and 233-236 (no. 103) on the rest of the astrolabe; and King, *In Synchrony with the Heavens*, XIVd “An astrolabe for the Sultan Ulugh Beg”: 751-774, esp. pp. 765-768.

labelled altitude scales with circular holes at each 5° from 0° to 90°. The ‘bald spot’ at the top of the sphere itself has a radius of about 15°-20° and is devoid of any markings. The author is at a loss to explain this except to note that constructing very small circles around the zenith on a sphere would hardly have been easy. On the other hand, the markings on MUSA are correct.

There is a lightly-coloured circle at the bottom of the sphere which is a ‘shadow’ of the circular base of the three prongs of the surrounding rete holding the sphere in place.

The latitude underlying the markings for the seasonal hours

The lower hemisphere shows first of all the lower halves of the meridian and the prime vertical. Then there are three parallel arcs of circles. The small circle closer to the north is the Tropic of Cancer; the small circle further from the north is the Tropic of Capricorn. The great circle arc in the middle is the celestial equator. Its extremities are marked المشرق , *al-mashriq* and المغرب *, al-maghrib*, east and west. Arcs of small circles have been drawn between the one-twelfth divisions of the solstitial circles: these represent the seasonal hours, labelled from 1 to 12. To understand the situation for the first and twelfth hours one must imagine away the scale below the horizon so that the parallel circles could all be seen encountering the horizon.

The latitude underlying these seasonal-hour markings is *ca.* 36°,[274] so that they would serve, say, Aleppo. To assume that these markings on ZAIM were indeed intended for Aleppo or somewhere on the parallel of 36° or the middle of the fourth climate would, however, be an error. See further below.

The rete

The rete consists of two main components. There is first a pierced hemispherical frame bearing the star-pointers. This has the ecliptic ring as base circumference. It is divided into 30° intervals for the zodiacal signs, subdivided in 5° intervals, and further subdivided into single degrees, more carefully than the horizon on the sphere. There is an equinoctial

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274 They are therefore similarly situated to those on TUNIS: for example, on both sets of markings, at the third seasonal hour at the summer solstice the sun would be on the prime vertical or E-W colure.

colure inclined to this and passing through the 'zenith'. Then there is a solstitial colure perpendicular to the horizon, also passing through the 'zenith'. On the colure starting from the Capricorn 0° on the ecliptic there is a double latitude scale consisting of two quadrants of scales separated by a space sufficient to receive a silver pin that can be adjusted on the scale and penetrate the appropriate hole in the sphere. The arguments on the right hand side of the double scale run from [0° at the top - 5 -] 10 - 5 - 20 - ... - 80 - 5 - 20 - 5 - ? at the ecliptic. On the left hand we find identical markings <u>in reverse</u>. It is not clear why the scales do not run from 0° to 90° as they do on MUSA. This can only be explained in terms of ineptitude. Within the two sides of this scale there is a runner which can be moved almost the entire length of the scales to set the latitude when the sphere is secured inside the rete. The scale extends to a decorative silver frame pierced by a hole marking the pole of the celestial equator. Two star-names are engraved on this frame – الفكة , *al-fakka* and الواقع , *al-wāqi*ʿ – and their two pointers extend like a *fleur-de-lys* to connect with another frame with another pair of pointers. This has no obvious practical function and is certainly not an indicator of the *qibla*, or local direction of Mecca, the sacred direction in Islam.[275] (If it were, of course, the approximate location of the maker could have been determined already.)

It must be noted that here, as on MUSA, considerable care has been taken by the designer or maker to ensure that a maximum of symmetry controls the star pointers. This achieves a sense of symmetry for the rete that is evident from all perspectives and is only occasionally interrupted by a small pointer here or there. The 'cost' of this is a severe limitation on the stars that can be represented under these constraints. We shall consider the 21 star-names and the positions of their pointers later.

The lower part of the rete consists of a frame of three arcs of circles attached to each other at a small circular button at the bottom. One of these branches is attached at longitude Virgo 0° = 150° to the ecliptic with a closed shackle and a fixed silver pin that cannot be removed. The other two are attached to the ecliptic at Taurus 0° = 30° and Capricorn 0° = 270° by means of shackles with removable silver pins.

A circular frame inclined to the plane of the ecliptic at about 23.5° represents a small circle parallel to the celestial equator and securely to the

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275 # This claim is made in [Hoare], "A highly important spherical astrolabe", p. 1, on which see n. 219. The decoration points towards Cancer 0° on the ecliptic scale.

north of the ecliptic, that is, away from the ecliptic scale. Its lowest point corresponds to Cancer 0° = 90° on the ecliptic scale and it is joined to that scale by two small stays. Its uppermost part is attached to the latitude scale between arguments 40° and 50°. Being parallel to the celestial equator it serves to measure arcs related to the equator, such as the day and night arcs of heavenly bodies or hour angles and right ascensions.

Various parts of the rete are made of silver or overlaid in silver. These include the throne and *fleur-de-lys*, both sides of the latitude scale, and the knobs on some seven star-pointers.

On part of one side of the ring attached to a shackle at the top of the throne there are a series of incisions which resemble a text, but not in any recognizable language, and certainly not Arabic or Hebrew or any number-notation.

The curious incisions on the suspensory ring of the instrument signed by ‘al-Zaʿīm’.

The star-pointers on ZAIM

To measure the longitude and latitude on ZAIM this author did not have the luxury of a reliable set of altitude circles at his disposal. So I first had to find any vertical scale on the sphere – here there are four, two fitted with holes and two without – and ensure that the star-pointer lies on that scale. Then I would line up the bottom of the rete with the horizon on the sphere. When this is achieved, the scale of the horizon, bur only the scale, will be visible all around the bottom of the rete. And the pointer will lie on the vertical scale on the sphere. The foot of the vertical scale on the sphere will then mark the longitude of the star on the ecliptic scale on the rete.

The pointer will mark the latitude of the star on the vertical scale on the sphere. The whole process is rather precarious because as soon as one fixes one pointer on a vertical scale one finds that the ecliptic on the rete has moved relative to the horizon on the sphere, and when one moves them together, one finds the pointer is no longer on the vertical scale.

This author has attempted to determine the coordinates of the 21 star pointers on the ZAIM instrument but is handicapped and cannot use his (former) principal hand. Errors may have been introduced during this procedure and the measurements have been repeated and the results averaged. First indications are that the main problem lies with the star-positions, not with the investigator.

The sub-group of stars on ZAIM that were not on MUSA were investigated from photos at the request of Ernesto Canobbio by Prof. Paul Kunitzsch.[276] He wrote:

> " ... I looked at the photos of the two astrolabes which you had included in your letter, and tried to read the star names on the star pointers of the two (which is of course not possible for every individual star, because the photos do not show each of them in a readable from). What I found in the 'new' astrolabe is quite a number of stars about whose identity and correct location I am in great doubt. It looks different from the first instrument and as if made by someone without well-based knowledge of these stars. Here I just give you some of the most outstanding and different names which seem to be different from the first astrolabe. I

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276 Letter of Paul Kunitzsch to Ernesto Canobbio dated 20.08.2017, in his inimitable style. The relevant text reads as follows (keep in mind that modern Arabic software does not print a carrier without dots such as we find throughout medieval texts and inscriptions – here square brackets are used to point out that the printed dots should not be there):

* رس الـــحوا (*sic* written), in about Taurus 25°; uncertain what it intends to mean, رأس الـــجوزاء , *ra's al-jawzā'*, "the head of Orion", $\lambda\varphi^{1,2}$ Ori, or رأس الـــحواء "the head of Ophiuchus", α Oph (but for this the location in Taurus would not fit).
* Opposite it, there is دنب الكاس [written without dots], i.e., *dhanab al-ka's*, "the tail of the bowl (Crater)", with in several aspects nonsense: on these astrolabes, only stars of the northern hemisphere are inscribed, but Crater belongs to the southern hemisphere; and what should "the tail" of the bowl, or Crater, be? So, doubtless, some nonsense. (It is placed in about Leo 7°, but this would also not fit a star of Crater in that period, about 15th century AD).
* قـــلب الاســـد *qalb al-asad*, "the lion's heart", α Leo, in about Virgo 8°. This could roughly fit; but in the first spherical astrolabe α Leo was not mentioned – so here different from no. 1.
* الكف الحصب [without dots] (wrongly spelled, for الكف الخضيب *al-kaff al-khaḍīb*, "the tinted hand", β Cas; here in about Leo 27°. In no. 1 it was correctly in Aries 28°.
* راس القوس [without dots], *ra's al-qaws*, "the head of the arc". In Aqr 11°. There does not exist such a name of a star in Sagittarius, to which the name (قـــوس *qaws*, "bow, arc") seem to point.
* نـــنره [without dots], letters which I cannot recognize as some written word, in Psc 26°.
* الرامح a*l-rāmiḥ*, "the lance bearer", a Boo, in Sgr 3°; BUT:
* الـــسماك الـــرامـــح *al-simāk al-rāmiḥ*, "the lance-bearing *Simāk*", α Boo, the same star with the same name of old-Arabic background, now in Tau 10° – *i.e.*, the same star, with the same name, in two different places, rather far distant from each other; in no. 1 it was in 236° longitude (= Sco 20°)."

> mention them here not in a specific order, but just so as they sprang to my eyes."

Whilst Kunitzsch was more concerned with the names on the pointers and was not in a position to investigate both the longitudes and latitudes of the stars, he was able to conclude correctly from this small selection:

> "From these examples you can see that something seems to have gone wrong in the fabrication of this ['new'] spherical astrolabe."

The 21 star-pointers are arranged as follows: 21 and 1-3 on the inclined vertical quadrant; 4 and 7 on the vertical fork; 5-6 on the silver 'throne'; 8-9 on the inclined vertical quadrant; 10-15 on the left semicircular frame; and 16-20 on the right semicircular frame.

LIST OF STARS ON THE ZAIM SPHERICAL ASTROLABE AND THEIR ECLIPTIC COORDINATES

Notes: The information given for each pointer is as follows. First, the name on the pointer, usually without points and without *hamza*s. Then the proper name and a translation, with an identification. The magnitude **M** of the star in the Ptolemy/Ulugh Beg tradition is given in bold font. This is on a scale of '1' for bright stars to '5' for dim stars, with nebulae marked as such; modern magnitudes are necessarily more precise but not relevant here. The longitude and latitude as measured on the instrument by the author, perhaps accurate to the nearest ±2°, follows. Then, after an asterisk, the longitude and latitude from Knobel's version of Ulugh Beg's star catalogue are given (UB); these coordinates can be considered as accurate for our present purpose. They are followed by the number in the above list for MUSA, if the star is present there, together with the longitude and latitude on MUSA spherical astrolabe as measured by Francis Maddison. Pairs or triplets of coordinates printed in **bold font** accord with each other, this relationship being here generously defined as having less than 10° divergence. The information is printed in small font because it is of no historical interest.

Vertical quadrant

1. السماك الرامح , *al-simāk al-rāmiḥ* — "the lance-bearing *simāk* (uplifted one)", S1 K41, α Boötis (Arcturus) **M1** – name applies to this pointer and no. 3, also (correctly) to no. 14
Arcturus is the only bright star on the rete! However, the position of this pointer (and that of no. 3) is incorrect.
7° / 62° * UB 197° / 31° – missing on MUSA in this position, but see nos. 3 and 14 below, as well as MUSA-12
VERY PROBLEMATIC! WRONG STAR-NAME

2. مــثلث , *muthallath* — رأس الــمثلث , *ra's al-muthallath* , "the vertex of the triangle (Triangulus)", α Trianguli **M3**
25° / 17° * UB 30° / 16°; MUSA-03: **34° / 16°**

3. السماك الرامح , *al-simāk al-rāmiḥ* — S1 K41, α Boötis (Arcturus) **M1**, name applies to both this pointer and no. 1
42° / 45° * UB 197° / 31° – missing on MUSA, but see no. 14: *al-rāmiḥ* below
VERY PROBLEMATIC! WRONG STAR-NAME!

Left of vertical frame

4. رس الحوا , *ra[']s al-ḥawwā* — رأس الحواء , *ra's al-ḥawwā'*, α Ophiuchi **M3**
52° / **35°** * UB 256° / **36°**; not on MUSA
This is probably an error for رأس الــغول , *ra's al-ghūl*, β Persei (Algol) **M2-3**, for which:
ZAIM: **52°** / 35° * UB **49°** / 22°; not on MUSA
PROBLEMATIC! WRONG STAR-NAME!

Silver 'throne'

5. الواقع , *al-wāqiʿ* — النسر الواقع , *al-nasr al-wāqiʿ*, α Lyrae (Vega) **M1**
69° / **69°** * UB 278° / **62°**; not on MUSA.
VERY PROBLEMATIC! For Vega the longitude is too high by 210°
WRONG STAR-NAME!

6. الفكة , *al-fakka* — This is not المنير من الفكة , *al-munīr / al-munayyir min al-fakka*, S2 K45, α Coronae Borealis (Alphecca) **M2**
109° / 67° * UB **215° / 45°** – MUSA-11 **218° / 45°**
VERY PROBLEMATIC! This pointer is clearly mislabelled (so that the above

information on MUSA is irrelevant). WRONG STAR-NAME!

Right of vertical frame

7. ذنب الكاس , *dhanab al-ka's* **[!!]**

"the tail of the cup", not a star-name, possibly a gross error for فوق الركبة , *fawq al-rukba*, "above the (right) knee (of Perseus), λ Persei, 17th star of Perseus, **M4**, as on MUSA-06
126° / 37° * UB 62° / 29°; MUSA-06: **120° / 37°**
PROBLEMATIC! Longitude too high by 60° on both ZAIM & MUSA, and latitude too high by some 10° on both; WRONG STAR-NAME

Vertical quadrant

8. الكف الخضب , *al-kaff al-khaḍ[ī]b*

الكف الخضيب , *al-kaff al-khaḍīb,* S7 K2, β Cassiopeiae **M3**
147° / **51°** * UB **28° / 51°**; MUSA-02: **28° / 55°**
PROBLEMATIC! Longitude too high by 120°, but only on ZAIM, not on MUSA

9. قلب الاسد , *qalb al-asad* **[!!]**

قلب الاسد , "the heart of the lion (Leo)", α Leonis (Regulus) **M1**
159° / 27° **[!!]** * UB 142° / 0°; not on MUSA with this name
THIS IS RIDICULOUS: Regulus should be on the ecliptic!
This appears to be a gross error for the star MUSA-08, القفزة الاولى , *al-qafza al-ūlā*, "the first leap of (the gazelles)", ν Ursae Maioris **M3-4**, which has the appropriate coordinates:
ZAIM-09: **159° / 27° * UB 150° / 26°** * MUSA-08: **153° / 27°**
VERY PROBLEMATIC!

Left semicircle **(2 out of 6 incorrect)**

10. ساق , *sāq*

ساق الاسد , *sāq al-asad*, perhaps = السماك الاعزل , *al-simāk al-aʿzal*, α Virginis (Spica) **M1** at 196°/-2° or "shin-bone of Boötes", η Boötis **M3** at 192°/28°; **PROBLEMATIC IDENTIFICATION**
198° / 22° * **UB 196°** / -2° **(Spica)** or **192° / 28° (shinbone)**; ZAIM-09: **193° / 25°**

11. منكب , *mankib*

المنكب الايمن من العواء , *al-mankib al-ayman min al-ʿuwāʾ*, "right shoulder (of Boötes)", δ Boötis

	M4-3 219° / **52° * UB 205° / 49°;** MUSA-10: **208° / 50°** **Longitude on ZAIM is 10° too high, corrected on MUSA**
12. كـلـه , *k-l-h* (*sic*) > فـكـة	الـمنير مـن الـفكة , *al-munīr / al-munayyir min al-fakka* "the bright star of the (broken) dish", α Coronae Borealis **M2** **219° / 52° * UB 215° / 45°**; MUSA-11: **218° / 45°** **STAR-NAME WRITTEN UNINTELLIGIBLY**
13. **ك لل** , *k-| l-l* (*sic*) > جنب , *j-n-b*	جنب الجاثي , *janb al-jāthī*, ζ Herculis **M3** **234° / 12° * UB 234° / 53°**; MUSA-13: **236° / 15°** **STAR-NAME WRITTEN UNINTELLIGIBLY**
14. الرامح , *al-rāmiḥ*	السماك الرامح , *al-simāk al-rāmiḥ*, α Boötis **M1** **238° / 28° *** UB 197° / 31°; MUSA**-**12 **230° / 32°** (see nos. 1 & 3 above) **PROBLEMATIC! Longitude too high by 30° on both ZAIM and MUSA**
15. الراعي , *al-rā'ī*	"the shepherd", α Ophiuchi **M3** **259° / 34° * UB 255° / 36°**; MUSA**-**14: **257° / 35°**
Right semicircle	
16. ذنب , *dhanab*	ذنب النسر الطائر , *dhanab al-nasr al-ṭā'ir*, "tail of the (flying) eagle", ζ Aquilae **M3** **277° / 38° * 283° / 36°**; MUSA**-**15: **283° / 36°**
17. منكب , *mankib* (*sic*) > منقار , *minqār*	مـنقار الـدجـاجـة , *minqār al-dajāja*, "beak of the chicken (Cygnus)", β Cygni **M3-4** **297°** / 57° * **UB 294° / 49°**: MUSA-16: **300° / 50°** with correct name **NAME INCORRECT!**
18. دلفين , *dulfīn*	ذنب الدلفين , *dhanab al-dulfīn*, ε Delphini **M4-3** **300° / 26° * UB 306° / 29° – MUSA-16: 311° / 30°**
19. راس القوس , *ra's al-qaws* [!!]	راس الـــفرس , *ra's al-faras*, "the head of the horse (Pegasus)", α and/or β Pegasi, both **M2-3** 3**09° / 17° * 315° / 20°** and/or **317° / 21°**; MUSA-19: **316° / 23°**

20. عنق , *ʿunuq* — عنق الفرس , *ʿunuq al-faras*, “the neck of the horse (Pegasus)”, ζ and/or ξ Pegasi, **M3-4** and **M4-5**
338° / 36° * UB 338° / 17° and/or **341°** / 18°; MUSA-18: **340° / 38°**
PROBLEMATIC! Both ZAIM and MUSA have a latitude too high by 20°

Vertical quadrant

21. سرة , *surra* — سرة الفرس , *surrat al-faras,* α Andromedae = δ Pegasi **M2-3**
358° / 24° * UB 6° / 25°; MUSA-01: **8° / 26°**

An analysis of the stars represented on ZAIM is superfluous, given the information we consider next. Also, there are abundant orthographic problems, which I have documented but omitted here.

I will confess to becoming enthusiastic about ZAIM when I found out that:

(1) Mūsà was associated with the Ottoman military and *Zaʿīm* is an Ottoman military term.

(2) The latitude underlying the seasonal-hour markings appeared to be the “paradigm” value 36°, used by such authorities as Hipparchus, Ptolemy and al-Bīrūnī.

(3) A few of the many errors on the star-pointers on ZAIM were found on MUSA.

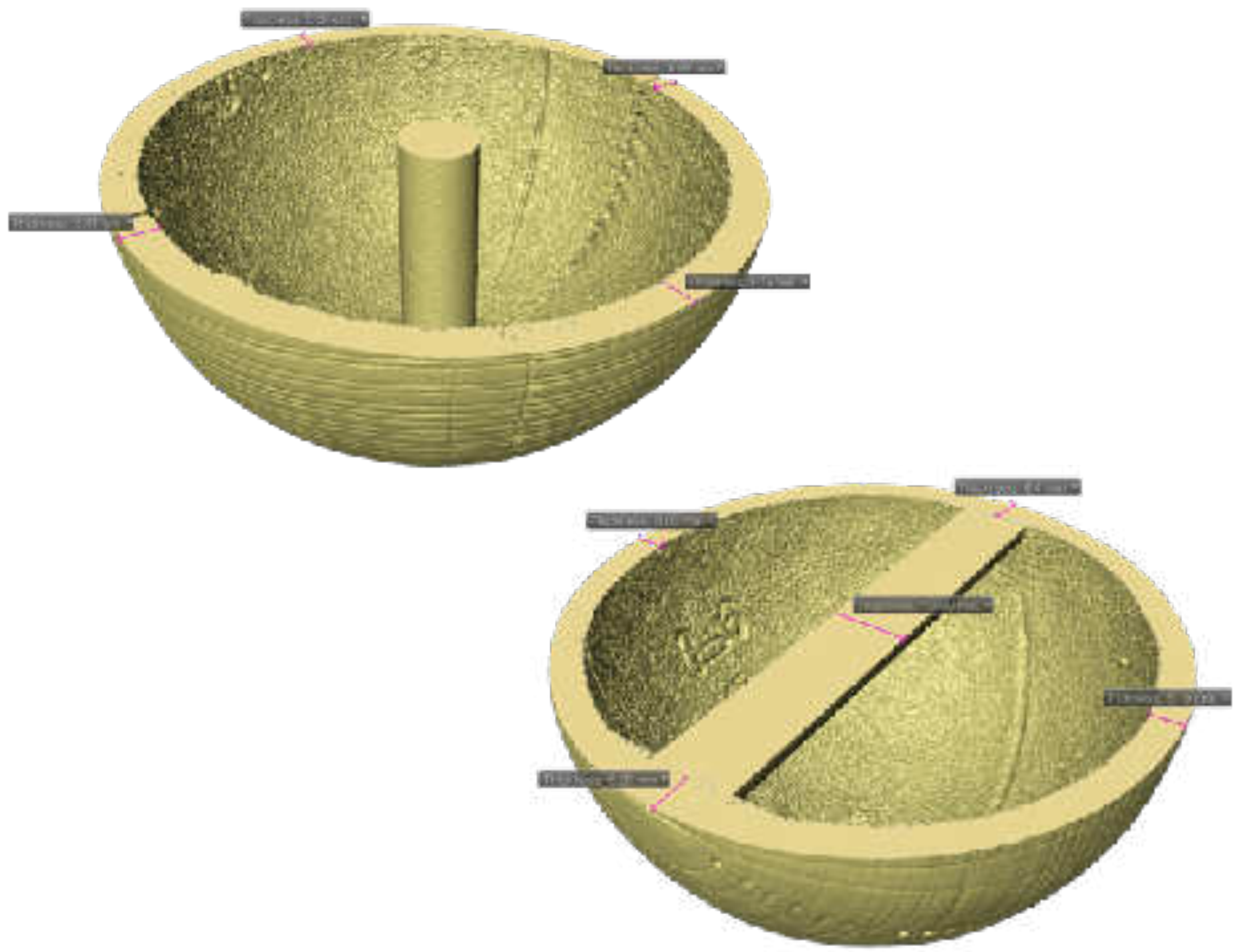
One could be fooled into thinking that ZAIM might be an early work, albeit incompetent, of someone associated with the military in Istanbul (with access to a cannon-ball or two) who later made MUSA. I was.

A look inside ZAIM

Several major surprises awaited this author as a report on an X-ray analysis of ZAIM reached him on 11 October 2018.[277]

It took a matter of seconds – as long as it takes to gulp – to establish definitively that ZAIM was a modern production, a few minutes more to realize that it was copied from MUSA essentially with the help of Francis Maddison's article, with even some significant input from TUNIS, no doubt using Ernesto Canobbio's article.

The illustrations reveal a cylindrical column joining the two poles, of thickness varying between 12.6 and 13.0 cm. This immediately explains the 'bald spots' on the outside of the sphere at its two poles. In other words, the column was inserted into the sphere after it had been moulded.



277 *X-Ray Analysis Report for Plowden & Smith Ltd.*, ref 87404.001 "Astrolabe", dated 09.10.2018.

Then there is some kind of ‘inscription’ embossed on the inside surface of the sphere. This has the appearance a combination of numbers such as one might expect on 19th- or 20th-century, or, more likely, 21st-century metalwork. The symbols are clearly numbers, and they are from different moulds, one set being heavier/thicker than the other. We could read twice, in two perpendicular directions, the number ’90’, with the ‘9’ and the ‘0’ separated by enough space to fit in one or two extra numbers, say ‘9 0’.

These two ’90’s, if such they are, perpendicular to each other, are so arranged that each interferes with the other. Thus the heavier number has the ‘9’ and the ‘0’ separated by the now horizontal ‘0’ of the other ’90’. The ‘9’ of the heavier ’90’ is well formed; the ‘0’ is damaged on the right hand side. The ‘9’ of the lighter ’90’ fades away at the bottom; the ‘0’ is damaged at the top where it encounters the ‘0’ of the heavier ’90’. The possibility should be kept that the two numbers represented are both ‘06’ rather than ‘90’, although this makes even less sense.

Now 90° is the altitude of the zenith of the observer, represented by the pole of the upper hemisphere. To mark it on the inside of the sphere would be sheer folly. To mark it twice would be crazy. And why mark it at all in a place where nobody will ever see it unless they damage the sphere or someone has it X-rayed?

The answer is surely that the hollow sphere was made commercially, and the embossed numbers are some kind of production marks. But why '90', and why twice?

We seek a company offering 10 cm diameter balls with a central cylindrical rod some 13 mm in diameter. My first link was to KING ARCHITECTURAL METALS, a U.S. concern, but they inevitably deal only in inches.[278] The Chinese company JINAN HUAWEI INTERNATIONAL TRADE CO. LIMITED of Guangdong offers brass spheres of 12 cm with an axial cylindrical screw of diameter 10 mm.[279] It goes beyond the scope of this study to determine the precise source of the sphere that was used to make ZAIM.

How the complicated rete was made for ZAIM will remain a matter of speculation. The first published images of the rete on MUSA separate from its sphere are, as far as I know, those made available in the present study!

A metallurgical investigation of ZAIM should have been a prerequisite when the object surfaced for the first time. Now it would be superfluous. I wonder whether the metallurgical analysis of historical instruments has progressed beyond where it was in the 1980s, when scholars pronounced on results of a single 'suspicious' 'unique' instrument without comparing them with analyses of anything else which might have been contemporaneous. Certainly a data-bank of information on a group of pieces from specific milieus (e.g., 10th-C Baghdad, 11th-C Cordoba, 14th-C Damascus, 15th-C Samarqand, 14th-C Catalonia, 14th-C England, 15th-C Vienna) would be very useful for a start. The only group of astrolabes that have to my knowledge been subjected to a serious metallurgical analysis are those of George Hartmann (Nuremberg, 1489-1564).[280] Apparently there is a radioactivity test that can determine whether or not (Y/N) a metal object predates *ca*. 1960 (Y) or not (N). This would have sufficed to show that ZAIM was a modern copy.

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278 http://steel.kingmetals.com/search?w=brass%20sphere (accessed 2018).

279 http://weiku991655.company.weiku.com/item/120mm-ss201-grade-copper-brass-stainless-steel-ball-with-10mm-screw-20264112.html (accessed 2018)

280 Gordon, "16th-century metalworking technology used in the manufacture of two German astrolabes" (1987), was the first of a series of studies.

Another look at ZAIM

Another look at ZAIM with this new information in mind reveals the following:

(1) The ‘bald spots’ at the poles result from the vertical cylinder inserted in the sphere.

(2) The upper hemisphere is incompetently engraved with altitude and azimuth circles, the former far poorly worked than the latter.

(3) The lower hemisphere are engraved with seasonal hours not for the latitude of the middle of the 4th climate but for the same latitude (to within a degree of latitude) that was used on TUNIS (which is more or less the same thing). The markings on MUSA are not clearly visible on available images, so those on TUNIS were preferred.

(4) The star-pointers on the rete are a total disaster. The few mistakes on MUSA are repeated but new confusion regarding names and positions is introduced. Any ‘new’ star-names that are introduced on ZAIM are taken from another source, such as an illustration of a standard astrolabe, without regard for their true positions.

What the maker of ZAIM needed for his task in addition to a reworked and appropriately aged brass sphere was illustrations of MUSA and TUNIS with which to make a 3-D model that he could turn into a spherical astrolabe. He could use the star-names in Francis Maddison’s list and just for fun threw in a few different ones with nonsense coordinates for a few dubious bright stars in the wrong positions such as Arcturus, Vega and Regulus.[281]

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[281] The procedure to make a “model” instrument of this kind is outlined in Keith Powell, “Keith’s spherical astrolabe” (1999-2002), at www.autodidacts.f2s.com/astro74xx/info/sph.html (accessed 2018).

On modern copies of Islamic astronomical instruments and deliberate fakes[282]

We should be careful to distinguish between COPIES of historical astronomical instruments, which are identified as such, and FAKES, whose purpose is to deceive, inevitably for financial gain.

The faking of Persian astrolabes began in Iran already in the 19th century, if not before. The beautiful little astrolabes of the celebrated ʿAbd al-A'imma (Isfahan, *ca*. 1700) tempted some metal-workers to try to copy them. Often the astronomical markings and the complicated Arabic inscriptions were too much for the forgers; nevertheless, the degenerate copies are found in major European and U.S. collections.

It continued in the mid 20th century when a physics professor from the American University of Beirut took illustrations copied from Gunther's *Astrolabes of the World* with him to Isfahan and showed them to some metal-workers there. His innocent initiative resulted in some acceptable copies of the splendid 17th-century Oxford Shāh ʿAbbās II astrolabe (Gunther, no. 18), whose present whereabouts are not known to me.

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282 The information in this section is culled from Gingerich & King & Saliba, "The ʿAbd al-A'imma astrolabe forgeries"; King, *Synchrony*, X "Astronomical instrumentation in the medieval Islamic world": 106-110 & XIVf "Brief remarks on astronomical instruments from Muslim India": 812-813; and *idem*, "The astrolabe" (2018). More complete bibliographical details are given in *Synchrony*.

Useful information on various fake astrolabes is found in François Charette, "Crude and fake astrolabes", in van Cleempoel, ed., *Astrolabes at Greenwich* (2001), pp. 308-319; and David Pingree, *Eastern Astrolabes in the Adler Planetarium and Astronomy Museum* (2009), esp. pp. 166-195.

The publication by Francis Maddison (and Emilie Savage-Smith), *The Nasser D. Khalili Collection of Islamic Art*, vol. XII: *Science, Tools and Magic* (1997), includes several fakes not identified as such; see King, "Cataloguing medieval Islamic astronomical instruments" (2000), esp. cols. 251, 257-258.

Fuat Sezgin & Eckhard Neubauer, *Science and technology in Islam*, vol. II: *Catalogue of the Collection of [copies of historical] instruments of the Institute for the History of Arabic and Islamic Science* (2011), p. 110, feature an obvious modern fake with the caption " ... made in Iran (Esfahan ?) in the year 1118/1706, ... an interesting example of the period of decadence in the use of the astrolabe in the Arabic-Islamic area, when people were no longer able to use it as an instrument for astronomical observations". The author(s) overlook(s) the fact that some of the most beautiful and most spectacular and most accurate astrolabes ever produced were made in Isfahan around 1700.

After the Iranian Revolution the faking of astrolabes moved from Iran to India. Some serious-looking instruments might even fool museum staff. One particular model included several features that are found on individual museum objects. These modern astrolabe copies, all of the same design, were on sale in India around 1990 for around $5,000 a piece.

Fake Maghribī astrolabes have appeared on the market too. My favourite is an astrolabe made for the famous 14th-century traveller Ibn Baṭṭūṭa to take on his world-voyage. In the 1980s it was on offer in Fez for $75,000.

Some seriously bad, monumental instrumental trash has appeared out of India in recent decades, absurd combinations of astrolabes and globes and armillary spheres that now feature in various executive board-rooms in the Arabian Peninsula. In Abu Dhabi the Miraj Museum has prepared a video of its rich holdings.[283]

I would not immediately wish to associate the 'new' spherical astrolabe ZAIM with these Indian productions, for the former is on a quite different level and, unlike the latter, it does not merit ridicule.

On a different level are the multiple instruments copied from real Islamic instruments at great expense for a new museum in Frankfurt by my former colleague, the late Prof. Fuat Sezgin. These are not 'real' copies for sometimes it was just a question illustrating the back and front, say, of an astrolabe. However good or bad the copies are they are sure to achieve the goal of impressing any visitor to the museum, which is normally closed. This author does not doubt their potential utility for serious researchers who will recognize their limitations. An extensive catalogue of the museum items, which include far more than just astronomical instruments, includes one item that is 'real', an astrolabe from the Institute's private collection, which just happens to be a real fake, wretched at that, which is treated as a genuine historical object. A copy of MUSA is of course in the collection (but no copy of TUNIS maybe because it was thought that incomplete unsigned instruments are not worth copying and/or displaying). And that is the main problem with the museum, apart from the fact that it was never open to the public, as with the offspring museums of the same kind in Istanbul, Dubai and Riyadh: they take all attention away from the real jewels of the history of Islamic astronomical instrumentation, which are preserved in real museums around the world but which attract very

283 "The Astrolabe. Miraj – The Museum, Abu Dhabi" (2016), at https://www.youtube.com/watch?v=05oSKvQ95JQ (accessed 2017).

little attention. People see these cheap copies and think they have "seen" some astronomical instruments from their illustrious past. As Nir Shafir so aptly put it in his brilliant 2018 article "Forging Islamic science":[284]

> "As fakes and fictions enter our digital bloodstream, they start to replace the original images, and transform our baseline notions of what actually was the science of the past."

Now some of Sezgin's instrument copies were made for him in Cairo. And that is perhaps, though not necessarily, where al-Zaʿīm was/is active. The people commissioned made several spherical astrolabes, probably all with diameter 8.3 cm, for 'museums' in Frankfurt, Istanbul, Dubai, Sharjah and Riyadh, and maybe elsewhere. Their copies of MUSA looks like nothing other than models, namely, brassy and shiny and actually rather cheap and nasty-looking. But more recently someone has had access to colour images of the real MUSA, easily available on the internet. He has acquired a brass sphere of diameter 10 cm, made an enlarged rete to fit over it, aged the metal components accordingly, and carefully imitated the inscriptions.[285] So ZAIM could have been inspired by an original commission from Frankfurt ... !

Now just who is the person who signed the 'new' instrument? He is the head of a small team, and either he calls himself "al-Zaʿīm" or his workers call him that. I shall call him that too. The name has for me pleasant connotations. In the late 1970s, Prof. E. S. (Ted) Kennedy, then recently retired from the American University of Beirut, joined me, the author (formerly his student), for two years at the American Research Center in Egypt to work on Persian astronomical manuscripts in various Cairo libraries. Ted used to jokingly call me "الزعيم , *al-zaʿīm*" because I was the project director and I arranged our not always easy access to the manuscripts. See further Appendix 2.

I think the real al-Zaʿīm is actually somebody independent of the Frankfurt-Cairo instrument copies. I think he is someone intellectually fascinated by these Islamic instruments. And I think he masters all sorts of techniques to reproduce them with an aged appearance. To do this he must

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284 Shafir, "Forging Islamic science".

285 This author has not been able to visit Sezgin's 'museum' in the past, but maybe somebody might check whether his copy of MUSA has seasonal-hours markings for 36° (as on TUNIS) or 41° (as on MUSA). For somehow, ZAIM has copied from MUSA and TUNIS.

read scholarly papers on unusual instruments. I can give just one specific example. In 2006 there was auctioned at Sotheby's of London a very remarkable instrument signed by Nasṭūlus, the leading instrument-maker in Baghdad around the year 900. It was a single circular plate bearing a series of horary markings on one side, specifically for the latitude of Baghdad. One should measure the solar altitude and insert it together with the solar longitude in the various scales and then the highly sophisticated curves would yield the time of day in seasonal hours. On the other side was a solar longitude / calendrical scale, which previously had been considered a later Western Islamic invention. The instrument was described in the Sotheby's catalogue and in the leading journal for the history of Islamic science.[286] In short, the instrument took us by surprise.

A couple of years ago, another example of this remarkable type of instrument appeared on the up-scale Islamic art market in London. It was virtually identical to the first, with one major difference. The 'real' instrument was slightly damaged: an unfortunate hole went right through the piece, just where the latitude 33° had been engraved, but this number was just visible. On the new instrument there was no hole and no latitude. *Ergo* ... .

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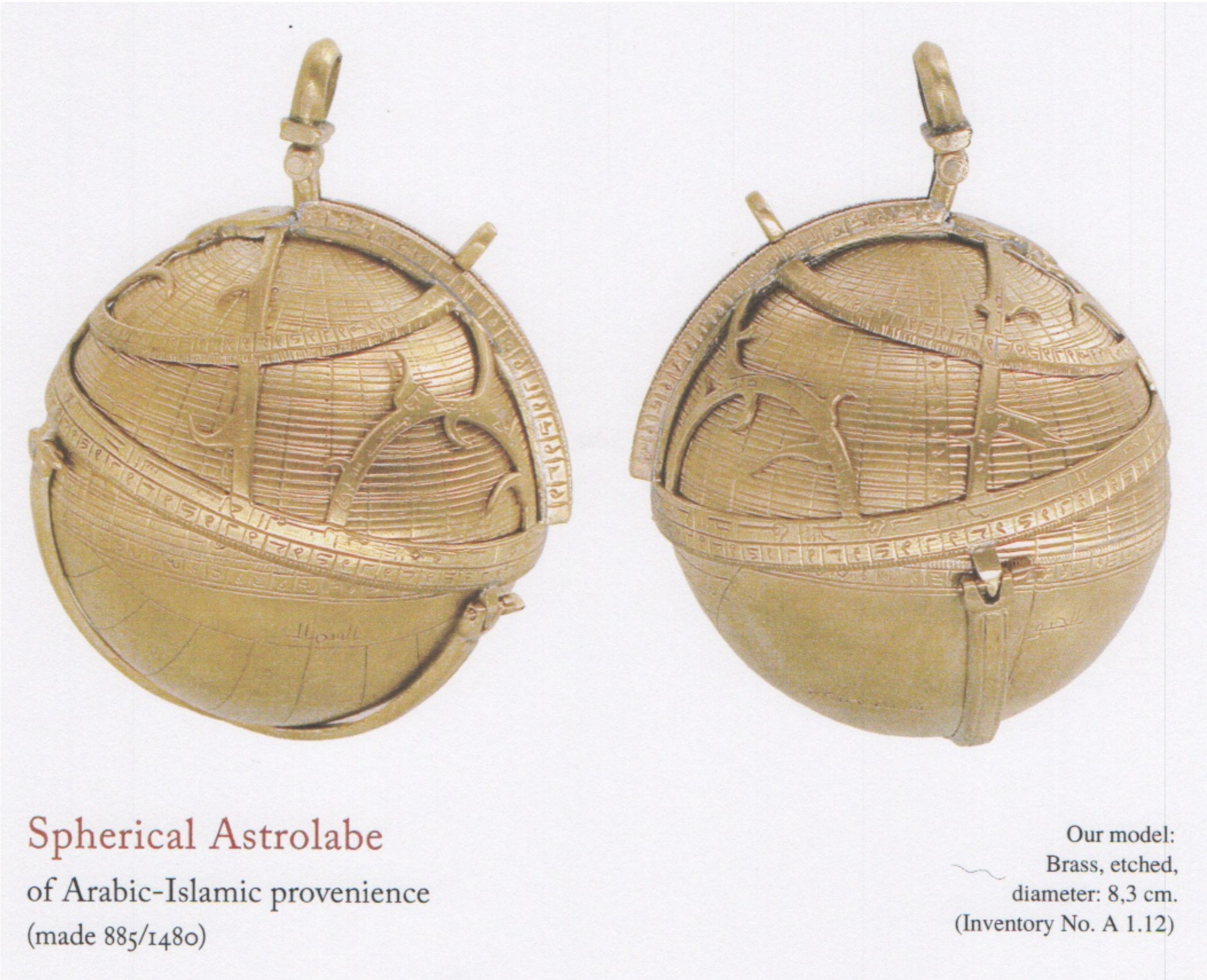
286 Sotheby's of London, *Arts of the Islamic World*, October 11, 2006, lot 87 on pp. 76-85; King, "An instrument of mass calculation made by Nasṭūlus in Baghdad *ca*. 900", *Suhayl – International Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* 8 (2008), pp. 93-119, repr. in Muzaffar Iqbal, ed., *Islam and Science: Historic and Contemporary Perspectives*, 4 vols., esp. III: *New Perspectives on the History of Islamic Science*, Aldershot & Burlington VT: Ashgate, 2011-12, pp. 243-269.



A copy of the Oxford spherical astrolabe of Mūsà commissioned by the late Fuat Sezgin for his 'museum' at the Institut für Geschichte der arabisch-islamischen Wissenschaften in Frankfurt. This is illustrated on p. 131 of his catalogue of his collection. One can immediately see here the problems with the altitude circles on the sphere.

The 'new' astrolabe by al-Zaʿīm might have hailed from the same Cairo workshop, but it seems more likely that it is the product of a very adept enthusiast for Islamic instruments who is cognisant of the latest writings on the history of Islamic instrumentations.

In any case, it has brilliantly fulfilled Nir Shafir's prediction.

12 Concluding remarks

Comparative remarks on the three spherical astrolabes

In the opinion of this author, TUNIS could date from the 14th or 15th century, the time of the most vigorous astronomical activity in Tunis. MUSA is an authentic instrument from the late 15th century. ZAIM is an enigmatic modern copy inspired mainly by MUSA but also, for the seasonal-hour markings, by TUNIS.

This is not the first time that a historical instrument has forced the rewriting of a small chapter of history but it may be the first time a modern copy has done that. And this is why research on primary sources, be they manuscripts or instruments (or sometimes even modern copies, if nothing else is available!), is so exciting.[287]

Mūsà again

Alas we have no person with who we can associate the Tunis instrument. However, at least we have a man called Mūsà, active in Istanbul around 1480 and even more so around 1500, in a milieu where astronomy had been cultivated for many centuries, at least by the previous inhabitants of a different culture, who was clearly competent in astronomy, extremely interested in instruments and constructing them. Furthermore he possessed extraordinary linguistic ability – at least Hebrew, Arabic, Latin, Turkish (resident in Istanbul), Italian (long-time visitor to Venice and Padua) and possibly Greek ('retired' in Crete). All the evidence points to the fact that it was Mūsà Jālīnūs who constructed a spherical astrolabe in Istanbul in 1480. The latitude-dependent markings on this piece are for the latitude of Istanbul. This is only a hypothesis, but it is the very first about the identity of 'Mūsà' to have been proposed in 60 years. Others may want to seek elsewhere for another, different Mūsà active in Istanbul around 1480 who was also fervently interested in astronomical instruments.

It is out of the question that the Oxford spherical astrolabe MUSA was intended as a gift for Sultan Bāyazīt II or his predecessor, or some other distinguished personage, for in those days every such gift, be it a treatise or an astrolabe, would mention the name of the recipient. And that gift, if a scientific instrument, should surely be a serious piece. We shall mention

287 King, *Astrolabes and angels*, p. 122.

below (Appendix 1) a qibla-indicator presented to Bāyazīt II's son Selim I around 1518 which was totally useless for any practical purpose. And we shall mention the useless remnants of a serious astronomical table that occur in the manuscript tradition associated with Mūsà Jālīnūs. Yet a spherical astrolabe could serve as a model or symbol of the universe. Certainly MUSA (and even ZAIM) are splendidly decorative and highly intriguing.

It will not hurt if this study with its challenging 'hypotheses' would inspire more interest in Islamic instrumentation in general, and no less in the medieval traditions of stellar coordinates and geographical coordinates, and even the afterlife of the climates of Antiquity in the medieval period. And hopefully the two historical instruments which we have discussed will inspire further research on the role of the spherical astrolabe in medieval Islamic astronomy.

We have discussed two genuine medieval instruments: the sadly incomplete, unsigned piece from Tunis and the late-15th-century from Istanbul signed by Mūsà. Together they constitute the only known examples of a sophisticated and complicated tradition of the construction of a very remarkable variety of astrolabe, otherwise known to us only from texts.

Appendixes

A1 A compass-bowl and an astronomical table

These two items – an astronomical instrument and an astronomical table – are of relevance to our study because the former was dedicated to the son of Bāyazīt II and the latter is somehow associated with the manuscript tradition of Mūsà Jālīnūs on Zacuto. Both are so corrupted and riddled with errors that they can serve no useful practical purpose. Yet the prototypes from which they were each derived, in both cases sophisticated tables, were commendably accurate.

The Damascus ceramic *qibla*-bowl for Sultan Selīm I – geographical data in distress

An example of a scientific object that is of no scientific value, yet is of considerable historical interest, is a glazed ceramic bowl from Damascus, *ca*. 1520, intended to serve as a 'wet' compass bowl (طاسة , *ṭāsa*, simply "bowl") as opposed to a dry one.[288] It is preserved in the National Museum of Damascus. Its purpose is to enable the user to lay out the *qibla* or local direction of Mecca for some 40 localities.[289] This *qibla*-bowl is of particular interest to the present study because **it was made by order of (برسم) the Ottoman Sultan Salīm (I, known as Yavuz, "the Grim"), the son of Sultan Bāyazīt II**, who ruled from 1512 to 1520 and essentially put an end to Mamlūk rule in Syria between 1516 and 1517 without either death or destruction (this happened just after he died in 1520). Since Salīm I is referred to as خادم الحرمين , *khādim al-ḥaramayn*, "servant of the two Holy Places (Mecca and Medina)", which his forces had captured by 1517, the qibla-bowl seems to have been made for him between 1517 and 1520.

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288 On the compass in the Islamic world see the article "Maghnāṭīs – ii. Compass" by Eilhard Wiedemann in *Encyclopedia of Islam*, 2nd edn. (from 1st edn.); Schmidl, "Two early Arabic sources on the magnetic compass"; and King, article "Ṭāsa (magnetic compass)", in *Encyclopedia of Islam*, 2nd edn.

289 On the sacred direction in Islam and the way in which it was determined see King, articles "Ḳibla" and "Makka as centre of the world" in *Encyclopedia of Islam*, 2nd edn., repr. in *idem*, *Astronomy in the Service of Islam*, IX-X, and the introductory sections to *idem*, *World-Maps*.

On the 'wet' variety the bowl is filled with water and a compass-needle, here missing, floats on top of it. The bowl is 30 cm in diameter and its rim is 1.9 cm high. Its surface is light brown in colour, although the small central circular space with the maker's name is white; the spaces for the place-names are coloured light green. All inscriptions are in black and in a heavy unpointed *kūfī* script.[290]

The bowl with its horizontal scale around the inside of the rim divided into 5°, then 1° intervals, can then be aligned in the cardinal directions. The *qibla* or direction of Mecca for a given locality can then be read off from the information on the inside of the bowl. Most of the information painted on the bowl – the *qibla* for 40 localities in Syria and Iran – is completely confused and, from a practical point of view, quite useless. Some of the data presented is, however, adequate to establish that it is corrupted from an enormous Iranian geographical table that is known to us and which showed the longitudes and latitudes of some 274 localities from the Iberian Peninsula to China with their qiblas and distances to Mecca computed with remarkable accuracy. Indeed, the qibla-values are mainly accurate to the nearest minute of arc. The table was compiled in Kish, south of Samarqand, in the first half of the 15th century; localities in Greater Iran are particularly well served.[291] I suspect that the Damascus qibla-bowl was copied from another one, possibly one broken in pieces. This would

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[290] al-Ush & Joundi & Zouhdi, *Catalogue du Musée nationale de Damas*, p. 227; King, "L'astronomie en Syrie à l'époque islamique", esp. "Bol de boussole" on pp. 440-441 (preliminary discussion, with maker's name incorrectly given as *shaykh* ... (?)); *World-maps centred on Mecca*, pp. 99-114, 168-170, 478-480 (**detailed analysis**), maker's name given as Shaykh Thābit; *idem*, article "Ṭāsa [= compass]" in *Encyclopedia of Islam*, 2nd edn., esp. p. 313 and pl. VII, fig. 1 (within context of the magnetic compass in Islam); and *idem*, *In Synchrony with the Heavens*, I "Astronomical instrumentation in the medieval Islamic world": 94 (brief reference).

The first part of the maker's name is properly identified in al-Moadin, "Qibla directional plate" and Zamani, "Enamelled qibla finder bowl from Damascus" (in Persian)", both innocent of the problems of the qibla data. However, the latter points to an error in my 1999 analysis (in *World-maps*): my no. 19 – Sabzavar should be Shiraz with qibla 58;38°, corrupted in a very obvious and typical manner (given the nature of the alphanumerical notation used by medieval astronomers) from the value 53;23° in the Timurid table (TMR120).

[291] On this table see King, *World-maps centred on Mecca* (1999), pp. 149-161 and 456-477. It was not previously known, so it is not featured in Kennedy & Kennedy, *Islamic geographical coordinates*.

account for the fact that several of the Iranian place-names are illegible or almost so, many unintelligible or strange to a Syrian eye, and the fact that the qibla-values are mainly meaningless yet bear evidence of their noble origins in the Timurid table. For an analysis of this geographical data in distress, the reader must refer to my detailed study published in 1999.

The reader should bear in mind that the heavy unpointed *kūfī* script is often barely intelligible and that some localities could only be identified from their qibla-values, not from their names. Likewise the instructions on the use of the bowl, written around the outside of the rim, as well as the dedication in four cartouches, are not brilliantly achieved.

The Damascus qibla-bowl. [Image from King, "L'astronomie en Syrie", pp. 440-441.]

We may never know how such a fine and rare artistic object could have been created with most of its geographical data in complete disarray. The maker is named as "Sayyid Thābit", otherwise unknown to us. The relevant inscription reads:

ʿamal Sayyid Thābit bi-Dimashq, عمل سيد ثابت بدمشق
"Made by Sayyid Thābit in Damascus".

It is not clear to this writer why Thābit chose to present data from an Iranian source when similar accurate data from a Syrian geographical table compiled some 150 years before his time would have been readily available to him in Damascus. The explanation appears to be that he was ordered to copy an Iranian qibla bowl with Iranian data on it and, as far as that data was concerned, he did not really know what he was doing. His new bowl itself is nevertheless a masterpiece of decorative art.[292]

This piece serves as evidence that a competent craftsman could make a scientific object that was defective for a sultan, not even knowing that the ruler was going to die not long thereafter.

A universal astronomical table for lunar crescent visibilty

Only one other instance comes to mind of hopelessly corrupt copies of an important astronomical work. This is a table for determining the possibility of lunar crescent visibility throughout the year in each of the seven geographical climates, that is, for the whole world, and it was published by this writer in 1987 from 15 copies found in manuscript libraries around the world.[293] There are seven sets of 12 values in degrees and minutes, one for each zodiacal sign of solar longitude. In theory, one should investigate the difference between the solar and lunar longitudes at sunset on the evening when visibility is anticipated, and see how it compares with the appropriate value in the table. If it is more, visibility is assured; if it is less,

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292 On contemporaneous ceramics from Damascus see Meinecke, "Syrian blue-and-white tiles", and further examples in Cluzan *et al.*, eds, *Syrie – Mémoire et civilisation*, pp. 456-461.

293 King, "Early Islamic tables for determining lunar crescent visibility", esp. pp. 197-207, on this particular table and the available copies thereof, and pp. 202-203 on the Mūsà connection. On the problem of visibility as treated by Muslim astronomers see my article "*Ru'yat al-hilāl* [= lunar crescent visibility]" in *Encyclopaedia of Islam*, 2nd edn.

the crescent will not be sighted and the operation should be repeated the next evening.

The universal table for lunar crescent visibility on the flyleaf of a copy of an Abbasid astrological treatise in MS Cairo Ṭalʿat *mīqāt* 119, fol. 1r. Note the paucity of dots on the letters representing the numbers.

The table may be of early Andalusī origin (10th or possibly 11th century?) but was copied later with considerable abandon in Fez, Tunis, Cairo, Sanaa and indeed even Istanbul. For any practical purpose it is virtually useless. It is nevertheless a very interesting table and nobody in modern times has been able to interpret it satisfactorily from a mathematical and/or statistical viewpoint, nor to explain how the entries in all 15 available copies could have become so meaningless. For in the case of this table for lunar visibility, all the dots were left off all the entries in the table at some stage in the transmission and then later some were replaced. But even when one attempts to restore the individual (84) entries, the structure of the table still presents a challenge.It is well documented that errors could creep into medieval Islamic tables with numbers expressed in alpha-numerical notation (*abjad*) as soon as copyists became careless about the dots, leaving them out here and there or altogether, and then later copyists putting them back at random.[294] A 57 , نز can be changed into a 17 , يز, and a 18 , يح into a 53 , نج, or *vice versa* in both cases, and worse.

Now it happens that two copies of the table, one from Egypt and one from the Yemen, occur in manuscripts of Arabic versions of Zacuto's canons to his *Perpetual Almanach*, the former from the version by Mūsà Jālīnūs.

Thus **the table occurs in the very Escorial manuscript of Mūsà Jālīnūs' rendition of Zacuto's tables** (ár. 966, copied after 1500 in Egyptian *naskhī* script). It is to be found at the end of the main tables (fol. 192v).

In the Milan Ambrosiana manuscript (C82, copied 1675) of a Yemeni copy of a Maghribī version of the Arabic canons from *ca*. 1630 the table occurs on the front-jacket and is copied in a different hand from the remainder of the work.[295] The table does not occur in the Cairo manuscript (Dār al-Kutub *mīqāt* 1081, copied *ca*. 1800) of a Maghribī version of Zacuto's tables.[296]

There is a sense in which this table, somehow associated with Mūsà Jālīnūs, is as impractical as the two spherical astrolabes which I believe can be associated with him. The difference is that the original table was probably carefully computed and was later rendered virtually useless for any serious purpose by careless copyists.

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294 On the possibility of errors creeping into medieval Islamic tables as a result of carelessness using the *abjad* notation see n. 270 above.

295 King, *Astronomy in the Yemen*, p. 7, n. 16; Parra, *Traducciones al árabe del* Almanach de *Zacuto*, p. 20.

296 King, *Cairo Survey*, nos. F31, F50; and Parra, *Traducciones al árabe del* Almanach de *Zacuto*, pp. 21-22.

A2 The word '*zaʿīm*' and the name and/or title '*al-Zaʿīm*'

I very much enjoyed writing this section during the summer of 2018 because it took me away from my usual pursuits. However, I have come to realize that the information presented here is essentially irrelevant to the subject of medieval spherical astrolabes. Nevertheless this section gathers information that is apparently not conveniently available elsewhere so I am disinclined to suppress it.
Instead, I dedicate it to the Zaʿīm who made the latest spherical astrolabe:
الى الزعيم الآلاتي من الزعيم السابق مع فائق احتراماتي وأطيب تمنياتي

"It were a work of too great labour considering the little satisfaction and delight it would afford the Reader, to proceed accurately in describing the just numbers of those which follow these *Zaims* ... ; it will be sufficient to denote, that the smallest number of a *Zaim* is four Men, ... and the highest of a *Zaim* to serve with Nineteen; so that whosoever will survey this *Turkish* Host, must make his Calculate a little more or less by conjecture and judgement. ... ... The *Zaims* or *Timariots* being aged, or impotent, have in their life-time power to resign up the Right of their Estates to their Sons, or other Relations. ... ... The foregoing account of *Zaims* and *Timariots* is the most reasonable one can be given: And because we have reckoned them at the lowest rate, making some allowance to the 83380, this Militia may amount to an hundred thousand Men, which, as I have heard, is the utmost number of this sort of Soldiery." Paul Rycaut (1628-1700), *The Turkish history from the original of that nation, to the growth of the Ottoman empire with the lives and conquests of their princes and emperours*, (1665), pp. 85, 87, 88.

The signature inside the ecliptic ring reads: عمل الزعيم , *ʿamal al-Zaʿīm*, "the work of al-Zaʿīm". This name is, at first sight, most unexpected. Or is it a name? Any attempt to decipher the word/name/title is not going to be exactly straightforward.

General comments

The use of the word *za'īm* in Islamic history could be the subject of at least a Master's dissertation. The materials presented below could serve as a guide for such a project, although our present purpose is far more limited: to try to understand WHY anyone would sign their handiwork عمل الزعيم , *'amal al-za'īm*, "made by al-Za'īm". Let us assume for moment that we are dealing with a genuine Ottoman astronomical instrument.

In modern Arabic, the word زعيم , *zaʿīm* , pl. زعماء , *zuʿamā'*, means "pretender" or "chief", from the verb زعم , *zaʿama*, "to maintain, allege, claim, ... "; used as a title or form of address, in some modern political (and also criminal circles) it means "leader" or "boss". Gamal Abdel Nasser (1918-1970) can be said to have been the ultimate (and last) Arab *zaʿīm* in the sense of "leader". In some contexts the word has a negative connotation:[297]

> "The *Zaʿim* system, also known as *zuʿamā* clientelism, is a corrupt patronage system ... . A political boss, known as a *Zaʿīm*, is from the leading family in the country's electoral districts. They manipulate elections and distribute political favours and financial rewards to the highest bidder. A *zaʿīm* can run for office or encourage votes for another (so as) to have (them) in his debt. Votes are often obtained through bribery or force. Individuals elected to parliament view their primary goal (as being) to serve the needs of their local clients, neglect any national issues and use parliament to further their regional-sectarian interests. The *Zaʿīm* dressed in tailored European suits, which misled many visitors at the time."

In the late 1970s, Prof. E. S. (Ted) Kennedy, then recently retired from the American University of Beirut, joined me, the author (formerly his student), in Cairo to work on Persian astronomical manuscripts in various libraries. Ted used to jokingly call me "الزعيم , *al-zaʿīm*" because I was the project director and I arranged our not always easy access to the manuscripts. On the days when we visited the libraries I indeed wore an Egyptian tailored suit, in an attempt to be taken seriously by the library staff, if not by my senior colleague.

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297 Article "Za'im system" at https://en.wikipedia.org/wiki/Za'im_system, where a longer version can be accessed. A milder version is in the anonymous article 'Zaim' in *The Oxford Dictionary of Islam*, 2003.

The name Zaʿīm in one form or another occurs today from Morocco to Indonesia, both as a first name and as a family name. Some examples: Ḥusnī al-Zaʿīm (1887-1949) was President of Syria or a few months in 1949 before he was executed. The title *Zaïm avec un Grand Z* relates to a 2012 book by Jean-Pierre Prault and concerns a family of boxers who moved from Algiers to the Ardennes. Feridun Zaimoğlu (the surname means "son of Zaim") is a German author and visual artist of Turkish origin (b. 1964). In Pakistan the name becomes 'Zaeem'. There a restaurant called 'Al Zaeem' in Cairo. Versions of these names are, of course, also found in the Arab and Muslim diaspora in Europe and the Americas. So, for example, we find in Berlin a restaurant called 'Zaim Falafel'. On a different level, ZAIMS is an acronym for some kind of engineering app called 'Zentech Asset Integrity Management Solution'.

The word *zaʿīm* in the *Qur'ān*

The word زعيم *zaʿīm* is used twice in the *Qur'ān*,[298] and this, one might think, could surely be sufficient in itself for it to be used as a personal name. The word means "guarantor, bail, surety, warrantor". One verse (68:40) reads: سَلْهُمْ أَيُّهُم بِذَٰلِكَ زَعِيمٌ , *salhum ayyuhum bi-dhālika zaʿīm*[un], meaning "Ask them: which one can guarantee that?". The word is used for a person who stands a surety on behalf of another, or is a spokesman of others. Thus, the verse is intended to mean: "Ask thou of them, which of them will stand surety for that", or in another modern rendering, "Which of you will come forward and say that he has made such and such a covenant with Allah on your behalf?". The other verse (12:72) occurs in the story of Joseph's sojourn in Egypt and concerns a missing goblet. The verse reads: قَالُوا نَفْقِدُ صُوَاعَ الْمَلِكِ وَلِمَنْ جَاءَ بِهِ حِمْلُ بَعِيرٍ وَأَنَا بِهِ زَعِيمٌ , *qālū nafqidu ṣuwāʿa 'l-maliki wa-li-man jā'a bihi ḥimlu baʿīr*[in] *wa-anā bihi zaʿīm*[un], meaning: "They said: We are missing the great beaker of the king; for him who produces it, is (the reward of) a camel load; I will be bound by it," or "They said: We are missing the measuring bowl of the king, and whoever can produce it, will be given the load of a camel; and I will be bound by this." In both verses the basic meaning is the same, but modern translations vary considerably. In Islamic tradition the Prophet Mūsà bears

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298 See *Qur'ān*, translation Yusuf Ali, pp. 1592 and 577-578, and also, for example, www.islamawakened.com/quran/roots/Zay-Ayn-Miim.html, and www.englishtafsir.com/Quran/68/index.html (Sayyid Abul Ala Maududi, *Tafhim al-Qur'an – The Meaning of the Qur'an*).

a special honorific title كـــليم الله , *kalīm^u ʻllāh*, "the one who speaks with God", or "the one who is addressed by God" (both meanings are mentioned by medieval commentators).[299]

The textual evidence

The *Onomasticon Arabicum* of the Institut de recherche et d'histoire des textes of the Centre national de la Recherche scientifique, which features 27,000 names of Muslim scholars up to the 16th century,[300] yields rather few results for a search on زعـــيم , *za'īm*. These represent all of the records (sources available on the *OA* website); they are all from the 11th and 12th centuries:

31445 – A certain al-Isfarāyinī, d. *ca*. 424 H (1033), was هُوَ الحَاكِم والزَعِيم بـــهَا and زَعِـــيم إســـفَرَايِـــين , *za'īm Isfarāyīn* and *huwa al-ḥākim wa-'l-za'īm bihā*, "the chief of (the town of) Isfarāyīn" and "he is the ruler and the chief in (Isfarāyīn)".

28494 – An unnamed individual, mentioned in 443 H (1051/52), was referred to as زوزن رئيـــسها زعـــيمها , *Zawzan ra'īsuhā za'īmuhā*, "the head and the chief of (the Iranian town of) Zawzan".

28311 – حي بن صاعد بن سيار القاضي , Ḥayy ibn Ṣā'id ibn Sayyār al-Qāḍī, "the judge", d. *ca*. 462 H (1069/70), was بن زعيم القَضَاء والزَعَامَة بهَرَاة مُدَّة, *za'īm al-quḍāt wa-'l-za'āma bi-Harāt mudda^tan*, "the chief of the judges and of the *za'āma* (office of the *za'īm*s) for a while".

13458 – Abu 'l-Ḥasan al-Ḥuṣrī al-Fihrī, d. 488 H (1095) was the زعـــيم الاندلس , *za'īm al-Andalus*, "the chief of al-Andalus".

9011-12 – A certain unnamed individual, d. *ca*. 500 H (1106/07), is referred to as أخُـــو أبِـــي الـــقَاسِـــم , *akhū Abi 'l-Qāsim za'īm al-ru'asā'*, "the brother of Abu 'l-Qāsim *za'īm al-ru'asā'*", featuring an imposing title "the boss of the chiefs". The father of the same Abu 'l-Qāsim, والـــد ابـــي القاسيم زَعِيم الرُؤَسَاء , is also mentioned.

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299 Article "Mūsà" in *Encyclopedia of Islam*, 2nd edn., by B. Heller and D. B. Macdonald, on cols. 639b-640a.

300 Available at http://onomasticon.irht.cnrs.fr. This is a research tool of great potential for investigators of Muslim history. The site suffers, however, from very strange und user-unfriendly access organization, to such an extent that this writer was unable to access it. An ID is necessary, but there is nowhere to find or to create an ID.

13683 – The well-known al-Ḥasan al-Sabbāḥ, d. 518 H (1124/25), known as صـــاحـــب الـــموت , *ṣāḥib Alamūt*, "the Master of the Fortress of Alamut", was also called زعيم الاسماعيلية , *za'īm al-Ismā'īliyya,* "the head of the Ismā'īlī (sect)".

29290 – A certain الـنميري , al-Numayrī, d. 588 H (1192) was لَـد زَعِـيم بَـنِي نُـــمَير , *walad za'īm Banū Numayr*, "the son of the chief of the (tribe of) Banū Numayr", and (?) وَلَد أُخت زَعِيم عُبَادَة , *walad ukht za'īm 'Ubāda*, "the son of the sister of *za'īm* / chief 'Ubāda".

9376 – Abu 'l-Futūḥ Shukr al-Ḥasanī, d. *ca*. 592 H (1196), was زعيم مكة , *za'īm Makka*, "the chief of Mecca".

The epigraphic evidence

The widespread use of the title *za'īm* in the medieval Islamic period, say, 12th to 16th centuries, is attested in Islamic epigraphy, and for this the *Thesaurus d'Épigraphie islamique* of the Fondation Max van Berchem (Geneva) prepared mainly by Ludvik Kalus could be invaluable.[301] Out of some 50 attestations of the title *za'īm* or *al-za'īm* from the 12th to the 16th centuries, in none of the sources is *za'īm* or *al-za'īm* used as a personal name.

Furthermore, not a single reference indicates that the person referred to was a normal mortal who happened to be a *za'īm* in the Ottoman military sense. Rather, we have about 15 attestations of the expression *za'īm al-juyūsh*, "chief of the armies", mainly when referring to rulers, as well as زعيم جيوش المسلمين *za'īm juyūsh al-Muslimīn*, "the chief of the armies of the Muslims", and زعيم جيوش الموحدين , *za'īm juyūsh al-muwaḥḥidīn*, "the chief of the armies of those who pronounce the unity of God".

The adjective *al-za'īmī* is often used alongside other noble epithets referring to virtues such as الـــعادلـــي , *al-'ādilī*, "the just", and الـــهمامـــي, *al-humāmī*, "the magnanimous", also when referring to rulers, particularly in Mamluk inscriptions. Here it seems that we are witness to a series of 'double adjectives' used only for rulers, formed by simply adding ي- , *-ī*, to an adjective reflecting a virtue, such as عـــادلـــي , *'ādilī*, from عـــادل , *'ādil*, "just". In the case of زعـــيمي , *za'īmī*, however, the adjective is formed from a noun زعـــيم , *za'īm*, and it surely in reference to the Qur'ānic use of the

301 Available at www.epigraphie-islamique.org (accessed in 2018). I thank Fathi Jarray for reminding me to consult the *Thesaurus*.

word with the meaning "guarantor" and related notions which have been mentioned above. Here is one example out of about 20 in the *Thesaurus*:

Fiche 34924 – *ca*. 900 H (*ca*. 1460) – Military Museum, Istanbul, inv. no. 08202: In the surviving part of an inscription in which the Egyptian Sultan Īnāl (one of two) is mentioned, he is referred to as المالكي الهمامي الناصري **الزعيمي** العالمي العادلي الكفيلي al-Mālikī al-Humāmī al-Nāṣirī **al-Zaʿīmī** al-ʿĀlimī al-ʿĀdilī al-Kafīlī.

Some examples of more general applications of the word that we are seeking to better understand:

Fiche 43312 – Syria, 585 H (1189-1190) – British Museum: "This is the grave of **الزعيم** معز الدين ... الملوك يوسف بن علي بن عمر ... الرواني , **al-Zaʿīm** Muʿizz [al-Dīn] ... al-mulūk Yūsuf ibn ʿAlī ibn ʿUmar ... al-Ruwānī – may God have mercy upon him. He died on Tuesday, the ninth of Ṣafar, in the year 585 ... ."

Fiche 36560 – 757 H (1356) – Savvaz, Iran: "This is the grave of ... **الزعيم** شمس الدين محمد بن محمود بن مهتر , **al-Zaʿīm** Shams al-Dīn Muḥammad ibn Maḥmūd ibn Mahtar – may God Almighty have mercy upon him and illuminate his grave – ... (?) he died on Saturday, 29th of Dhu 'l-Ḥijja in the year 757."

Fiche 12863 – 967 H (1559/60) – Tripoli (Lebanon): The construction of a mosque by العبد الفقير محمود ابن المرحوم لطفي **الزعيم** , "the wretched slave (of God) Maḥmūd son of the deceased Luṭfī **al-Zaʿīm**" ... .

Fiche 22323 – 982 H (1574/75) – Erzincan, Turkey: "This Great Mosque (المسجد الجامع) was built in the days of ... السلطان مراد بن سليم Sultan Murād ibn Salīm by **الزعيم** حاج مصطفى بن خواجة سيدي قوله , **al-Zaʿīm** Ḥājj Muṣṭafà ibn Khōja Sayyidī Qawala in the year 982 (Hijra)."

The title *zaʿīm* in Ottoman Turkish military and land tenure organisation

The article "*Zeʿāmet*" (from Arabic زعامة , *ziʿāma*, 'that which is held by a زعيم , *zaʿīm*') in the first edition of the *Encyclopaedia of Islam* (1913-1936) by the French Orientalist and Turcologist Jean Deny (1879-1963)[302] covers many meanings of the word '*zaʿīm*', and underlines its significance in Ottoman military organization. The origins of the system

302 Article "*Zeʿāmet*" in *Encyclopedia of Islam*, 1st edn., by Jean Deny, mentions a 1931 article in Turkish on the *Tīmār* system by C. H. Becker.

appear to be in Seljuq rather than Byzantine practice, and it is surely highly significant that there are, as we shall see, two different and distinct groups, one with an Arabic name, the other with a Persian name.

There is a clear account of Ottoman land tenure, albeit only for the 19th century, amongst some notes collected by the economist Rod Hay from a 19th-century French overview of Turkish land laws.[303] In a short notice on landed property in Egypt and Turkey we find:

> "The constitution of property in Turkey is similar to what it is in Egypt. We here transcribe a sketch of it, as given in some interesting letters, which appeared in the *Economiste français* (September, 1873). With the exception of the مــلك , *Mulk* lands which are private property, the soil has but one proprietor, the State. This, however, is the classification of land as established by the old law (مــلتقى *, Multequa*), the principal provisions of which have been re-enacted in the law at present in force, that of June 21, 1868:
>
> 1. ملك , *Mulk* lands, the absolute property of individuals;
> 2. مــيري , *Emirié* [*Mīrī* < *Amīr al-mu'minīn*] land, the domain of the State, granted by it, on certain conditions, to individuals;
> 3. وقف ج. اوقاف , *Vacoufs*, property that is tied up. ... ;
> 4. متروكة , *Metrouké* lands, belonging to the State, and granted by it for public use;
> 5. مــوت , *Mevat* (dead) lands, belonging to the State, and granted to individuals at its pleasure.
>
> Mulk lands. ... .
>
> Emirie lands. *Emiré* [*Mīrī*] lands, constituting the larger portion of the territory of the Empire, belong to the State. They are derived, in great measure, from the old fiefs, which were granted to military chiefs, on condition of their rendering personal aid, at the head of a certain number of horsemen, in wars offensive or defensive. **These fiefs were of two sorts: the تيمار , *Timar* (in Persian, to nourish or tend) and the زعامة ,**

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303 Rod Hay, "Landed property in Egypt and Turkey", Ch. 25 in the Archive for the History of Economic Thought at McMaster University ("an attempt to collect in one place a large number of significant texts in the history of economic thought"), at https://socialsciences.mcmaster.ca/econ/ugcm/3ll3/ ... continuing with ... laveleye/ PrimProp25.htm

> ***Ziamet*** **(from زعـــيم , *zaim*, chieftain).** The law of April 21, 1858, abolished these fiefs. ... ."

The further we go back in Ottoman history the more we are confronted with the *Zaʿīm*s and the Timariots and their military connotation. For example, *zaʿīm* is described as a 'rider' in the late Ottoman army: in this painting from the H. J. Vinkhuijzen collection of military costumes in 1805 the title is "Zaims, eine andere Art Türkischer Reuter", meaning "Zaims, another sort of Turkish rider", 'Reuter' being Middle High German for 'Reiter', 'rider', whence also 'Ritter', 'knight'.[304] Elsewhere the *Zaʿīm*s are likened to 'barons'. But there is a lot more .... .

A *zaʿīm* featured in the H. J. Vinkhuijzen collection of military costumes (1805) housed in the New York Public Library.

(The reader may imagine my joy upon locating this very nice image.)

304 Plates dated 1805 from a Vinkhuijzen album labelled: *Vorstellung der vorzuglichsten Gattungen des Türckischen Militairs und ihrer Officiere*, New York Public Library, at http://warfare.ga/Ottoman/byEuropeans/1805-Ottoman_Soldiers.htm?i=1.

For example, in Charles James' *Military Dictionary* of 1810 we find:[305]

> "Zaims. Principal leaders or chiefs; after whom a mounted militia, which they support and pay, is called among the Turks. One class of the Zaims receives its appointment direct from the Porte, and the other from the Beglierbegs. Whenever an order is issued by the latter for that purpose, the whole body of the Zaims must assemble, with their followers, at a given spot of rendezvous. They are supported by certain revenues called Timars; and the money which they thence receive amounts to twenty thousand aspers—five aspers are equal to one penny English—and they never can receive less. The Zaims are all of equal rank among themselves. They may be considered as the chief noblemen in Turkey; deriving considerable importance from the many privileges and immunities which are attached to their several Zaimets, (the places, situations, &c. where a Zaim receives his revenue, &c). ... ... "

Yet more information is provided in the authoritative *History of the Turkish Empire* by the British diplomat and historian Sir Paul Rycaut (1629-1700), available in English (1665, revised 1686) and in French (1678),[306] all versions now being available on the internet. This includes not only reasonably clear statements on the role of *Zaʿīm*s and Timariots, but also a detailed register of the numbers of troops they can muster in each region (*sanjaq*) from one end of the Empire to the other, counting a total of 83,380, rounded to some 100,000 (see the quote at the beginning of this section), and various customs and laws relating to them.

Perhaps the main difference between the *Zaʿīm*s and Timariots was that the latter outnumbered the former by about 8:1. In some recent discussions the

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305 Articles "Zaim" and "Ziamet" in James, *Military dictionary* (1810), II (unpaginated).

306 Rycaut, *History of the Turkish empire* (1665) / *Histoire de l'état présent de l'Empire Ottoman* (1678): The French version available on the internet is prepared from the original and is superior to the "Early English Books" rendering of the English version. The contents are as follows: *French* — Chapitre II : De la Milice des Turcs (p. 408) ; Des Zaims & des Timariots (p. 409); Ch. III : Calcul des forces que l'on tire des Zaims, & des Timariots (pp. 412-428) ; Ch. IV : De certaines coûtumes qui se pratiquent parmi les Ziamaets & les Timariots (pp. 428-430). *English* — Ch. II: Of the Turkish Militia / Of the Zaims and Timariots (p. 84); Ch. III: "A Computation of the numbers of the Forces arising from the *Zaims* and *Timariots*" (pp. 85-87), and Ch. IV Of certain Customs and Laws observed amongst the Zaimets and Timariots (pp. 86-88). 1686 edition: pp. 326-342.

*Zaʿīm*s have lost out to the Timariots altogether.[307] First, in the *Encyclopaedia of Islam* (2nd edn., 1960-1980) there is a singularly uninformative article "*Ziʿāmet*".[308] Even in works on Ottoman military organization we find:[309]

> "The timar fiefs and the related bureaucratic surveillance system provided the Ottoman sultans in the fifteenth and sixteenth centuries with a standing provincial cavalry army of 50,000–80,000 strong, while relieving the central Ottoman bureaucracy of the burden of revenue-raising and paying military salaries."

Likewise in the 2009 *Encyclopedia of the Ottoman Empire* the term *zaʿīm* is not mentioned at all although *tīmār* is mentioned dozens of times, and *ziamet* is grudgingly explained in the glossary.

Whilst none of the above-mentioned sources gives any information on the state of affairs regarding *Zaʿīm*s in 15th-century Istanbul, perhaps others can access some modern Turkish works dealing precisely with that subject in detail, or better, some contemporaneous Ottoman archives.[310] Until then, these few Western sources may suffice to give a general idea of the status and duties of the *Zaʿīm*s.

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307 Beldiceanu, *Le Timar dans l'État Ottoman : (début XIVe - début XVIe siècle)*, book and article, (1980); Darling, "Timar-holding Ottoman elite in the 16th-17th centuries" (2014-15) and "Historicizing the Ottoman *timar* system: Identities of *timar*-holders, 14th-17th centuries" (2017).

308 Article "*Ziʿāmet*" in *Encyclopedia of Islam*, 2nd edn., by the renowned Ottoman historian Suraiya Faroqhi.

309 Agoston, article "Ottoman military organization (up to 1800)", in Gordon Martel, ed., *The Encyclopedia of War*, Blackwell, 2012, p. 3 of 9 pp.

310 Beldiceanu, *Les actes des premiers sultans conservés dans les manuscrits turcs de la Bibliothèque Nationale* à *Paris. I. Actes de Mehmed II et de Bayezid II du ms. Fonds turc ancien 39* (1960).

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First-rate images of all three instruments were kindly made available by David Sulzberger, who in 2017 with singular astuteness arranged that all three spherical astrolabes could be examined together at the Museum of History of Science at Oxford, thanks to the good graces of the Director Silke Ackermann. Stephen Johnston of the Museum kindly provided significant details about the Oxford instrument.

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DAK, 24 November 2018

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