Out of Maragha:
Observations, Teachings, and Translations

Christine Roughan
New York University

Abstract

This paper examines the context for the Greek translations and adaptions of Islamic astronomical works which came out of Maragha and Tabriz at the end of the thirteenth century. It discusses the observation programs and the teaching activities of astronomers at the Maragha Observatory in order to shed light on the relation of the translated texts to the intellectual activities at the observatory and to the broader picture of education in the astral sciences in these two cities. The paper argues that astronomical education in these centers drew from a combination of more established teaching texts and of newer works by the astronomers and teachers at the observatory, and that the selection of sources that received translations and adaptions in Greek was motivated by the particular needs of the Byzantine student or students in question.

Key Words

Astronomy, Gregory Chioniades, Maragha Observatory, education.

The end of the thirteenth century saw a variety of texts and tables enter into Greek from Arabic and Persian astronomical works. Many of these have been attributed to the Byzantine scholar Gregory Chioniades, who is reported to have travelled to Persia, studied astronomy there, and brought back works which he translated into Greek.

In general throughout the medieval period, translations of Islamic astronomical material into Byzantine Greek were scattered and variously motivated – while a source text may be identified, the context in which it entered Greek is often unknown. It is a different story for this grouping of translations and adaptions from the thirteenth century. Several of them speak to having come from teaching contexts in Tabriz, the Ilkhānid capital. All of them entered Greek in the half century after the founding of a significant and long-lived observatory in Tabriz's neighboring city, Maragha. This small cluster of Greek translations serve as a case where something can be said about the context of the translations.

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While scholarship on this cluster of translations has acknowledged these teaching contexts, there has been little examination into what form astronomical teaching in thirteenth-century Tabriz and Maragha actually took. What kinds of texts might be taught to the student of astronomy in Maragha and Tabriz? To what extent did those pedagogical texts present the most up-to-date astronomical data that was available from work at the Maragha Observatory? And to what extent do the texts that received translation into Greek reflect those pedagogical texts?

Section I of this paper will offer a brief historical overview of astronomical activities in thirteenth-century Maragha and Tabriz. Section II will introduce the cluster of relevant Greek translations and the Arabic and Persian sources behind them. Sections III, IV, and V will show how these intellectual centers brought together scholars who engaged in both astronomical observation and teaching. It will be seen that there was a wealth of new astronomical data available from the efforts of the same individuals who taught the astral sciences and who wrote didactic texts on the subject. The astronomical texts taught in these centers thus comprised a range of material. Section V will in particular highlight the example of Bar Hebraeus as an astronomical student in Maragha, since there survives evidence to show that he worked with a range of different subjects and texts within the astral sciences. The texts read by students will show that while newer works that presented the results of the latest observation programs did receive attention, other existing texts by the relevant teachers along with more established texts formed the larger part of what was taught. With this examination of the astral sciences' study in Maragha and Tabriz complete, section VI will return to the cluster of translations that entered into Greek out of this pedagogical context. It will show how the texts that were translated fit into the picture developed in the prior sections. It will furthermore argue that the particular selection of texts that the Byzantine student or students studied (and ultimately translated and adapted) was likely motivated by the particular needs of that student or those students in question.

I. *Historical Background: Maragha and Tabriz*

Maragha Observatory was founded in 1259 by the order of the Ilkhānid ruler Hülagü Khan. Its establishment is set against a backdrop of Hülagü Khan's ongoing campaigns in Western Asia. In 1258 the Ilkhānids had captured Baghdad and conquered the fractured ʿAbbāsid Caliphate; in 1260 their conquests in Syria brought an end to the Ayyūbid dynasty. The Ilkhanate united these territories and several other Muslim states of the period such as the Nizari Ismāʿīlī state. Hülagü Khan established Maragha as the Ilkhanate's capital.

In the preface to his *Zīj-i Ilkhānī*, Naṣīr al-Dīn al-Ṭūsī reports that Hülagü Khan ordered him to observe the stars and that he and the other astronomers chose

Maragha as the site for the observatory. Biographical sources report that al-Ṭūsī, already a part of Hülagü Khan's court, had come to the khan with the request to construct an observatory in Maragha. This request was granted, and the observatory even secured *waqf* funds for its continuing activities.[1] The Maragha Observatory would bring together personnel from across the Ilkhanate.[2] Research at this observatory led to new astronomical tables, mathematical models, and planetary theory.[3]

The construction of the observatory included the construction of a library. Bar Hebraeus reports studying at this library and describes it as preserving the books of the Syrians, Arabs, and Persians.[4] Fourteenth-century biographers report that books were collected from Baghdad, Syria, and al-Jazira; they put the number of books at the library at 400,000 volumes. While there is likely exaggeration here, the observatory library did collect books seized in the course of the Mongol

1 For the text of the *Zīj-i Ilkhānī*'s preface, see John Andrew Boyle, « The Longer Introduction to the *Zij-I-Ilkhani* of Nasir al-Din Tusi », *Journal of Semitic Studies*, 8/2 (1963), p. 244–254. For al-Ṣafadī's report on al-Ṭūsī, see Aḥmad Al Arnā'ūṭ, Turkī Muṣṭafá (eds.), *al-Wāfī bi 'l-wafayāt*, Dār Iḥyā' al-Turāth al-ʿArabī, Beirut 2000, p. 146. The waqf fund is often pointed to as one of the factors which contributed to the length and success of the observatory, since with this fund it was able to persist after the death of its original patron Hülagü Khan in 1265 and its original director al-Ṭūsī in 1274. Naturally, the continuing favor of the khans remained an important factor as well: on their continuing patronage, see Qiao Yang, « Like Stars in the Sky: Networks of Astronomers in Mongol Eurasia », *Journal of the Economic and Social History of the Orient*, 62 (2019), p. 394.

2 In the preface to the *Zīj-i Ilkhānī*, al-Ṭūsī names in addition to himself four other scholars involved in the observation program at Maragha: Muʾayyid al-Dīn ʿUrḍi of Damascus, Fakhr al-Dīn Khilāṭī of Tiflīs, Fakhr al-Dīn Marāghī of Mosul, and Najm al-Dīn Dabīrān of Qazvīn. For this preface, see Boyle, « The Longer Introduction to the Zij-I-Ilkhani of Nasir al-Din Tusi », p. 246. This is not a comprehensive list of all the figures involved in observation programs in Maragha – it makes no mention of astronomers such as Muḥyī al-Dīn al-Maghribī or, later, Shams al-Dīn al-Bukhārī. In addition, far more individuals were present in the observatory in other capacities: teachers, students, librarians, scribes, and scholars of non-astronomical subjects. The biographical dictionary *Talkhīṣ Majmaʿ al-Ādāb fī Muʿjam al-Alqāb* by the observatory's librarian, Ibn al-Fuwaṭī, offers insight into many of these figures. For the edition, see Muhammad al-Kazim (ed.), *Talkhīṣ Majmaʿ al-Ādāb fī Muʿjam al-Alqāb*, Vezarat-e Farhang va Ershad-e Eslami, Tehran 1955. Unfortunately the treatise survives only partially and Ibn al-Fuwaṭī's other works on the observatory are no longer extant.

3 As is frequently the case for the astral sciences in this period, these advancements were intended to serve astrological purposes. This is supported by an anecdote about Hülagü Khan's initial reluctance to build the observatory where al-Ṭūsī responds by stressing that the astral sciences are valuable for the foreknowledge they provide. He provides the khan with an example to show that this foreknowledge is beneficial even if one cannot change what would come to pass. See Aydin Sayili, *The Observatory in Islam and Its Place in the General History of the Observatory,* Türk Tarih Kurumu Basımevi, Ankara 1960, p. 202. The anecdote in question appears in Al Arnā'ūṭ, Muṣṭafá (eds.), *al-Wāfī bi 'l-wafayāt*, p. 147.

4 Bar Hebraeus, *The Chronography of Abu'l-Faraj Bar Hebraeus*, trans. Ernest Wallis Budge, Oxford University Press, Oxford 1932, p. 2.

conquest, leading to a significant collection.[5] While the library was associated with the observatory, these descriptions make it clear that its contents were not limited to works on the astral sciences. This library would have served to attract scholars to Maragha just as the experts located at the site did.

The city of Tabriz, approximately 77 km north of Maragha, came to replace it as the capital of the Ilkhanate during the reign of Abaqa Khan (*r.* 663–680/1265–1282). Tabriz saw the growth of its own scholarly community: several scholars practiced in the astral sciences settled and engaged in teaching there, as is evidenced by Quṭb al-Dīn al-Shīrāzī and his students and by Shams al-Din al-Bukhārī and Chioniades.[6] In 1300, Ghāzān Khan ordered the construction of an observatory in Tabriz after visiting Maragha and being impressed by the astronomical activities there.[7] Unfortunately nothing is known about what observations or other activities were carried out at the observatory in Tabriz.

This paper considers Maragha and Tabriz together as related intellectual centers. While several of the Greek translations discussed in this paper are known to derive from their translator's studies at Tabriz, the Maragha Observatory was the center of gravity that had first amassed astronomical expertise and produced new data and theories in the latter half of the thirteenth century. As will be seen, multiple individuals who worked in Maragha spent time or settled in Tabriz. They contributed to the transmission of material out of Maragha.

II. *The Islamic Sources of the Greek Translations and Adaptions*

Groupings of astronomical and astrological treatises derived from Islamic sources appear in several Greek manuscripts from the fourteenth century onwards.[8] The treatises which receive focus in this article are the following:

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5 As recorded in al-Ṣafadī and al-Kutubī. See in the respective editions Al Arnā'ūṭ and Muṣṭafá (eds.), *al-Wāfī bi 'l-wafayāt*, p. 146 and ʿĀdil Aḥmad ʿAbd al-Mawjūd (ed.), *Fawāt al-wafayāt*, Dar al Kotob al ilmiyah, Beirut 2000, p. 251. Unfortunately, little evidence is available regarding the sizes of library collections in this period. The exception is the catalogue of the Ashrafīya library in thirteenth-century Damascus. Hirschler describes its collection of 2000 books as a « remarkably large collection for an unremarkable library in Damascus »; see Konrad Hirschler, *Medieval Damascus: Plurality and Diversity in an Arabic Library. The Ashrafiya Library Catalogue*, Edinburgh University Press, Edinburgh 2016, p. 3. Since Maragha's library contained the collections of Baghdad among other cities, it should be expected to be at least an order of magnitude larger.

6 Yang, « Like Stars in the Sky », p.395–396. Al-Shīrāzī's *Faʿalta fa-lā talum* seems to suggest a network of scholars present in Tabriz: see Ragep, « New Light on Shams », p. 235.

7 See Rashīd al-Dīn's report in Muḥammad Rawshan, Muṣṭafā Mūsavī (eds.), *Jāmiʿ al-Tawārīkh*, vol. II, Alborz, Tehran 1994, p. 1296 and 1340.

8 Three of the significant manuscripts for the texts discussed here are Rome, Vaticanus graecus 211 (before 1308 CE), Florence, Biblioteca Medicea Laurenziana, Plut. 28.17 (1323 CE), and Rome,

1. a translation of the *Zīj al-ʿAlāʾī*,[9]
2. a translation of the *Zīj al-Sanjarī*,[10]
3. the *Persian Syntaxis* of Chrysokokkes (ἐξήγησις εἰς τὴν σύνταξιν τῶν Περσῶν), possibly based on several *zījes*,
4. the *Revised Canons*, which depends on several *zījes*,[11]
5. the *Schemata of the Stars* (περὶ τῶν σχημάτων τῶν ἀστέρων), perhaps drawn from a *hayʾa* treatise,[12]
6. a translation of a work on the astrolabe (ποίημα τοῦ Σιὰμψ τοῦ Πέρσου περὶ τῆς διδασκαλίας τοῦ ἀστρολάβου),[13]
7. and *On the Genethialogical Computation* (περὶ τῆς ἐκβολῆς τοῦ ψήφου τοῦ γενεθλιαλογικοῦ), showing a worked example of a horoscope for an individual born on 25 August 1268 in Tabriz.[14]

Several of the works in this list are *zījes*, i.e., astronomical handbooks which provided tables and procedures for calculating the positions of the sun, moon, and planets. These were a standard genre of the Islamic astral sciences. Conversely, *hayʾa* treatises dealt with cosmographical subjects, focusing more on geometrical models and the configuration of the universe. The following overview will highlight the Arabic and Persian sources that have been identified or proposed for each of these Greek translations and adaptions. This will allow for a comparison of these works with what texts the Islamicate sources show were being used for astronomical study in Maragha and Tabriz.

The *Zīj al-ʿAlāʾī* was an originally Arabic text that was composed in the twelfth century by ʿAbd al-Karīm al-Shīrwānī al-Fahhād (*fl.* 575/1180). Al-Fahhād is reported to have composed five *zījes* in addition to this, but none of these six *zījes*

Vaticanus graecus 1058 (14th–15th cent.). They are described in David Pingree, *The Astronomical Works of Gregory Chioniades*, vol. I: *The Zīj al-ʿAlāʾī*, Gieben, Amsterdam 1986, p. 23–28.

9 For the edition and discussion, see ibid., p. 36–243.

10 For the edition and discussion, see Joseph Gerard Leichter, « The Zīj al-Sanjarī of Gregory Chioniades: Text, Translation and Greek to Arabic Glossary », Ph.D. Diss., Brown University 2004.

11 For the edition and discussion, see Pingree, *The Astronomical Works of Gregory Chioniades*, p. 21–22 and 260–333.

12 For the edition and discussion, see Emmanuel A. Paschos, Panagiotis Sotiroudis, *The Schemata of the Stars, Byzantine Astronomy from A. D. 1300*, World Scientific, Singapore 1998.

13 For the text of the preface and discussion of the treatise, see Elizabeth A. Fisher, « Arabs, Latins, and Persians Bearing Gifts: Greek Translations of Astrolabe Treatises, ca. 1300 », *Byzantine and Modern Greek Studies*, 36/2 (2012), p. 168–175.

14 For the edition, see Pingree, *The Astronomical Works of Gregory Chioniades*, p. 242–259.

are extant today. A report from a later *zīj* by al-Fārisī records that the data in the *Zīj al-ʿAlāʾī* was based on observations made in 541/1176.[15]

The *Zīj al-Sanjarī* was written in the twelfth century by Abū Manṣur ʿAbd al-Raḥmān al-Khāzinī (*fl.* 509/1115), the Greek slave of Shaykh al-ʿAmīd al-Qāḍī Abū al-Ḥasan ʿAlī ibn Muḥammad al-Khāzin. In 1131 al-Khāzinī produced an epitome of this text, titled the *Wajīz*, which is the version which was translated into Greek.[16]

George Chrysokokkes writes that his *Persian Syntaxis* (*c.* 1347) made use of astronomical tables which Gregory Chioniades had translated into Greek. There has been some disagreement over exactly which tables this treatise depends on. Mercier argued that Pingree was incorrect to point to the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* as sources for the *Persian Syntaxis* and he instead put forth the *Zīj-i Ilkhānī* (670/1272) as the primary source. Pingree reemphasized his position in an article responding to Mercier, holding that material was indeed drawn from the former two *zījes* in addition to material from the *Zīj-i Ilkhānī*.[17] The first two *zījes* have already been introduced; the latter *zīj* was the work of Naṣīr al-Dīn al-Ṭūsī, who wrote the treatise for his patron Hülagü Khan and completed it during the reign of his successor, Abaqa Khan. It was originally composed in Persian, though al-Ṭūsī did produce an Arabic version as well. The *Zīj-i Ilkhānī* was an important product of al-Ṭūsī's work at the observatory at Maragha, as will be discussed further below.

The *Revised Canons* draws upon several *zījes* throughout its text, directly citing the *Zīj al-ʿAlāʾī*, the *Zīj al-Sanjarī*, and the *Zīj-i Ilkhānī*.[18] Pingree sees this text as the work of Chioniades demonstrating his ability to use the tables in the *Zīj al-ʿAlāʾī*; Ragep, conversely, notes that this might simply be the work of Shams al-Dīn al-Bukhārī himself.[19] In any case, at least parts of the *Revised Canons* are derived from the oral teachings of Shams al-Dīn al-Bukhārī.[20]

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15 Pingree, *The Astronomical Works*, p. 7–8.

16 Leichter, « The Zīj al-Sanjarī of Gregory Chioniades », p. 6–8.

17 David Pingree, « Gregory Chioniades and Palaeologan Astronomy », *Dumbarton Oaks Papers*, 18 (1964), p. 142; Raymond Mercier, « The Greek 'Persian Syntaxis' and the Zīj-i Ikhān », *Archives internationales d'histoire des sciences*, 34 (1984), p. 37–38. Pingree subsequently responded to Mercier's argument in David Pingree, « In Defence of Gregory Chioniades », *Archives internationales d'histoire des sciences*, 35 (1985), p. 436–438.

18 See e.g. Pingree, *The Astronomical Works of Gregory Chioniades*, p. 307 and 319 for the first two and the last, respectively.

19 Ibid., p. 21; F. Jamil Ragep, « New Light on Shams: the Islamic Side of Σὰμψ Πουχάρης », in Judith Pfeiffer (ed.), *Politics, Patronage and the Transmission of Knowledge in 13th–15th Century Tabriz*, Brill, Leiden 2014, p. 236. Mozaffari raises the idea that the *Revised Canons* was part of a preliminary version of Shams al-Dīn al-Bukhārī's *Zīj muḥaqqaq al-sulṭānī* (*c.* 1320), though further research is needed to establish a connection. See S. Mohammad Mozaffari, « Astronomical Observations at the Maragha Observatory in the 1260s–1270s », *Archive for History of Exact Sciences*, 72 (2018), p. 593.

20 See chapter 27 of the text in Pingree, *The Astronomical Works of Gregory Chioniades*, p. 307.

The Greek treatise *Schemata of the Stars* has a format quite like an *hayʾa* treatise, albeit a rather short one.[21] It has received some attention in the secondary scholarship because one of its manuscripts contains a diagram that closely matches the figure used by al-Ṭūsī in his demonstration of what is today called the Ṭūsī couple – an important new mathematical device with a parallel found later in Copernicus.[22] This figure shows the author or translator's familiarity with a concept found first in al-Ṭūsī's edition of the *Almagest* (644/1247) and later elaborated in his *Ḥall-i Mushkilāt-i Muʿīnīye* (643/1245) and his *al-Tadhkira fī ʿilm al-hayʾa* (659/1260–1).[23] This figure and other similarities that are present in the text have caused some scholars to posit that the *Schemata of the Stars* was a translation of an Arabic work related to al-Ṭūsī's *Tadhkira*. The recent editors of the *Schemata of the Stars* see it instead as an original work by a Byzantine author who was adapting and extending Islamic astronomical material. Ragep argues that it is a translation of fragments of earlier treatises written in Persian by al-Ṭūsī: his *Risāla-yi Muʿīniyya* (632/1235) and its appendix, the *Ḥall-i Mushkilāt-i Muʿīnīye*.[24] If this is correct, then the *Schemata of the Stars*'s apparent similarity to the *Tadhkira* is a result of it drawing on earlier works by al-Ṭūsī whose theories and models would be finalized in the later text.

The treatise on the astrolabe listed above was translated from an Islamic work: it displays both transliterated vocabulary and topics relevant to the Muslim hours

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21 Ragep, « New Light on Shams », p. 238.

22 The manuscript in question is Vaticanus graecus 211, and the figure appears on fol. 116r. For discussion of this mathematical device, see Mario Di Bono, « Copernicus, Amico, Fracastoro and Ṭūsī's Device: Observations on the Use and Transmission of a Model », *Journal for the History of Astronomy*, 16 (1995), p. 133–154 and F. Jamil Ragep, « The Origins of the Ṭūsī-Couple Revisited », in Alexander Jones and Christián Carman (eds.), *Instruments – Observations – Theories: Studies in the History of Astronomy in Honor of James Evans*, New York University Faculty Digital Archive, New York 2020, p. 229–237.

23 George Saliba, Edward Stewart Kennedy, « The Spherical Case of the Ṭūsī Couple », *Arabic Sciences and Philosophy*, 1 (1991), p. 286. For the dating of the *Tahrir al-majisti* and the *Tadhkira*, see George Saliba, « The Role of Almagest Commentaries in Medieval Arabic Astronomy: A Preliminary Survey of Ṭūsī's Redaction of Ptolemy's Almagest », *Archives internationales d'histoire des sciences*, 37/118 (1987), p. 5–6. For the dating of the *Ḥall-i Mushkilāt-i Muʿīnīye*, see Ragep, « The Origins of the Ṭūsī-Couple Revisited », p. 229.

24 For the relation to the *Tadhkira*, see Noel M. Swerdlow, Otto Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus*, vol. I, Springer, New York 1984, p. 47–48. Swerdlow and Neugebauer assume this to be a translation by Chioniades. For the argument that it is an original composition, see Paschos, Sotiroudis, *The Schemata of the Stars*, p. 16–17. They follow Pingree, « Gregory Chioniades and Palaeologan Astronomy » in noting Chioniades as the likely candidate, though acknowledge that there is no definitive evidence. For the argument that it translates the *Risāla-yi Muʿīniyya*, see Ragep, « New Light on Shams », p. 240–242. For further details on the *Risāla-yi Muʿīniyya* and the *Ḥall-i Mushkilāt-i Muʿīnīye*, see F. Jamil Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy (al-Tadhkira fī cilm al-hay'a)*, vol. I, Springer Science+Business Media, New York: 1993, p. 65–70.

of prayer. The translator's name is preserved as Σιὰμψ τοῦ Πέρσου in the title and preface. If this is Shams al-Dīn al-Bukhārī, it is not impossible that he was the author of the original work as well.[25]

On the Genethialogical Computation lastly is an example of a worked horoscope. It uses the example of an individual born in Tabriz in 1268. Pingree presumes that Shams al-Dīn al-Bukhārī was the original author.[26]

This overview of the sources shows that they are primarily astrological material: zijes, worked problems, a text on the astrolabe, and a horoscope. Cosmography is covered by the *hayʾa* text. Most of these treatises rely on tables and numerical parameters – parameters which could be updated and improved through observation programs, such as the ones that had already been completed at the Maragha Observatory.

Despite this, the sources listed above are largely not the most recent and up-to-date astronomical works. By the time Gregory Chioniades (or perhaps any of his contemporaries) would have come to Tabriz in the 1290s, the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* were already a century or more old. The *Risāla-yi Muʿīniyya* was sixty years old, written prior to al-Ṭūsī's time in Maragha, and already superseded by the updated *Tadhkira*. Even the product of al-Ṭūsī's Maragha observations, the *Zīj-i Ilkhānī*, makes less use of astronomical observations than another *zīj* available at the time, as will be discussed below.

III. *Three Scholars at Maragha and Tabriz*

Key scholars at Maragha and later Tabriz were involved both in new astronomical research (updating parameters through observational activities) and in didactic activities (producing editions of curricular texts and teaching). The following brief overviews of three astronomers in particular – Naṣīr al-Dīn al-Ṭūsī, Muḥyī al-Dīn al-Maghribī, and Shams al-Dīn al-Wābkanawī (plausibly Shams al-Dīn al-Bukhārī) – will introduce relevant aspects of their astronomical activities and how they came to work at Maragha. The subsequent sections will discuss their observational activities and the experience of their students in more detail.

Naṣīr al-Dīn al-Ṭūsī (d. 672/1274) came from Tus, was educated in Mosul and previously worked in the Nizari state.[27] He acquired a respected position in Hülagü Khan's court after the khan conquered the Nizari Ismāʿīlī fortress at Alamut in

[25] Fisher, « Arabs, Latins, and Persians bearing gifts », p. 168–170. There does exist a Persian treatise on the astrolabe, *Kitāb-i Maʿrifat-i usṭurlāb-i shamālī* by Shams al-Dīn al-Wābkanawī (who has been plausibly identified as Shams al-Bukhārī, as will be elaborated below). It is possible that this was the source of the Greek translation, but this has not yet been confirmed: see Ragep, « New Light on Shams », p. 243–244.

[26] Pingree, *The Astronomical Works of Gregory Chioniades*, p. 21; Ragep, « New Light on Shams », p. 16.

[27] For a recent overview on al-Ṭūsī, see Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy*, p. 3–23.

1256. By this time al-Ṭūsī was already accomplished in the astral sciences: prior to this date he had written works such as his *Risāla-yi Muʿīniyya* and his edition of the *Almagest*. Indeed, during his time in the Nizari state he additionally produced his own editions of Euclid's *Elements* and the Middle Books (*Kutub al-Mutawassiṭāt*), the latter of which was a series of texts which had a history of being studied between Euclid's *Elements* and Ptolemy's *Almagest*.[28] As noted, al-Ṭūsī's output at Maragha included his *Tadhkira* as well as his *Zīj-i Ilkhānī*, the latter of which presented the results of his observation program. He wrote in both Arabic and Persian.

Muḥyī al-Dīn al-Maghribī (d. 682/1283) was responsible for the second major *zīj* to come out of observations at Maragha: the *Adwār al-anwār* (675/1276–7). He came from al-Andalus and previously worked in Syria under the Ayyūbids, where he composed his first *zīj*.[29] Al-Maghribī was captured during Hülagü Khan's campaigns in Syria in 1260 and it was his expertise with the astral sciences which saved his life, according to the account which he himself told to Bar Hebraeus. Upon hearing about al-Maghribī's astronomical expertise, Hülagü Khan sent him to Maragha to take part in the work there.[30] Like al-Ṭūsī, al-Maghribī's work at Maragha included both observations and teaching. He wrote in Arabic.

A figure similarly involved in observations, *zīj* writing, and teaching was Shams al-Dīn Muḥammad ibn ʻAlī Khwāja al-Wābkanawī. Recent studies have plausibly identified this figure with the Shams al-Bukhārī who taught Gregory Chioniades in Tabriz.[31] He hailed from the small village of Wābkana near Bukhārā. He was present at the observatory by 1272, as is evidenced by an astronomical observation

[28] For al-Ṭūsī's description of the Middle Books, see AL-ṬŪSĪ, « Kitāb Mānālāwus », *Majmūʻ al-rasāʾil*, vol. II, Hyderabad-Deccan, 1939–40, p. 2. He completed his edition of the *Elements* in 646/1248, as is recorded in the edition's colophon. (See for example British Library Add MS 23387, fol. 216v) Colophons in the manuscripts of al-Ṭūsī's *Taḥrīr al-Mutawassiṭāt* show dates of completion between 651–653/1253–1255. According to Kâtip Çelebi, the edition of Menelaus's *Spherics* was completed later in 663/1265 (hence, during al-Ṭūsī's time at Maragha); see GUSTAV LEBRECHT FLÜGEL (ed.), *Lexicon bibliographicum et encyclopaedicum a Mustafa ben Abdallach Katib Jelebi, dicto et nomine Haji Khalfa, celebrato compositum*, vol. I, Printed for The Oriental Translation Fund of Great Britain & Ireland, London 1835, p. 391.

[29] For more on Muḥyī al-Milla wa al-Dīn Yaḥyā Abū ʿAbdallāh ibn Muḥammad ibn Abī al-Shukr al-Maghribī al-Andalusī, see e.g. IBN AL-FUWAṬĪ, *Talkhīṣ Majmaʿ al-Ādāb fī Muʿjam al-Alqāb*, vol. V, p. 115; GEORGE SALIBA, « An Observational Notebook of a Thirteenth-Century Astronomer », *Isis*, 74/3 (1983), p. 391–392; and MERCÈ COMES, « Ibn Abī al-Shukr », in *Biographical Encyclopedia of Astronomers*, Springer, New York 2014.

[30] See the account by Bar Hebraeus in ANṬŪN ṢĀLIḤĀNĪ AL-YASŪʿĪ (ed.), *Tārīkh Mukhtaṣar al-Duwal*, al-Maṭbaʿa al-Kāthūlīkīyah li l-Ābāʾ al-Yasūʿīyīn, Beirut 1958, p. 280–281.

[31] For an overview, see BENNO VAN DALEN, « Wābkanawī », in *Biographical Encyclopedia of Astronomers*, 2014. On the identification of Shams al-Dīn al-Bukhārī with al-Wābkanawī, see MOZAFFARI, ZOTTI, « The Observational Instruments at the Maragha Observatory after AD 1300 », p. 53 and RAGEP, « New Light on Shams », p. 243–245.

he reports making in Maragha during that year.[32] If indeed the Shams al-Dīn al-Wābkanawī known from the Islamic sources can be identified with the Shams al-Bukhārī of the Greek sources, then he would have been 18 at the time of this observation.[33] Al-Bukhārī therefore numbered among the next generation of scholars at the observatory. He worked in both Maragha and Tabriz.[34] Like al-Ṭūsī and al-Maghribī, al-Bukhārī's astronomical work and observations led to the production of a *zīj*, the *Zīj muḥaqqaq al-sulṭānī* (completed between 716–736 / 1316–1335). Al-Wābkanawī worked in both Arabic and Persian, though it is possible he wrote more in the latter language. Despite the Arabic title of his *zīj*, its text is in Persian.[35]

IV. *The Observation Programs at Maragha*[36]

The biographer al-Ṣafadī presents a report from al-Ṭūsī which summarizes the history of astronomical observations leading up to the work at Maragha. He lists the observations of Hipparchus, those of Ptolemy, those for al-Maʾmūn in Baghdad, those of al-Battānī in Syria, those for al-Ḥākimī in Egypt, and those of Ibn al-Aʿlam in Baghdad. Al-Ṭūsī then notes that the latter two are the best of the listed observations, but are themselves over two hundred and fifty years old.[37] With this record of significant observations, al-Ṭūsī situates the work at Maragha as the latest in a long history and as a necessary update to astronomical data that was two and a half centuries out of date.

The report preserved in al-Ṣafadī additionally notes that a full observation program should properly extend for thirty years, as this is the time required for all planets to have completed their revolutions. However, Hülagü Khan desired the observations be completed in twelve years and so al-Ṭūsī sought to do so. This is

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[32] Mozaffari, Zotti, « The Observational Instruments at the Maragha Observatory after AD 1300 », p. 53.

[33] Shams al-Bukhārī's date of birth is recorded as 11 June 1254; see Pingree, *The Astronomical Works of Gregory Chioniades*, p. 16.

[34] Mozaffari, Zotti, « The Observational Instruments at the Maragha Observatory after AD 1300 », p. 49, fn. 9 discusses datable observations made by the astronomer that show he made observations at Maragha both before and after the years he is known to have been in Tabriz.

[35] As noted in van Dalen, « Wābkanawī ». The text has not yet been edited. Al-Wābkanawī also is known for a treatise on the astrolabe written in Persian. He has additionally been raised as a possible author for a Persian treatise on observational instruments: see Mozaffari and Zotti, « The Observational Instruments at the Maragha Observatory after AD 1300 », p. 80.

[36] This section will focus on Maragha since, as noted above, nothing is known about the activities at the Tabriz Observatory.

[37] Al Arnā'ūṭ and Muṣṭafá (eds.), *al-Wāfī bi 'l-wafayāt*, p. 150. The relevant *zījes* in this list are Yaḥyā ibn Abī Manṣūr's *al-Zīj al-Maʾmūnī al-mumtaḥan* (9th century), al-Battānī's *Kitāb al-Zīj* (10th century), Ibn Yūnus's *al-Zīj al-kabīr al-Ḥākimī* (*c.* 1000), and Ibn al-Aʿlam's *zīj* (variously known as *al-Zīj al-ʿAḍudī*, *al-Zīj al-Sharīf*, and *al-Zīj al-Baghdādī*) (10th century).

perhaps intended as an explanation for why the *Zīj-i Ilkhānī* was produced in 1272, after only twelve years of work at the observatory. Al-Bukhārī similarly stresses that the *zījes* from Maragha available to him had not accomplished a thirty-year observation program.[38]

Recent scholarship has shown that there were three observation programs which occurred at Maragha. These included observations by al-Ṭūsī and observatory staff made through 1272, which were used in the *Zīj-i Ilkhānī*; al-Maghribī's observations between 1262 and 1274, which were used in his *Adwār al-anwār*; and al-Bukhārī's observations between 1272 and 1305–6, which were used in his *Zīj muḥaqqaq al-sulṭānī*. Al-Bukhārī's observations were intended to test al-Ṭūsī's *Zīj-i Ilkhānī* and al-Maghribī's *Adwār al-anwār*.[39]

The *Zīj-i Ilkhānī* is usually viewed as the major product of the observatory at Maragha. Much of it, however, is derived from older material (the *zījes* of Ibn Yūnus and Ibn al-Aʿlam). Further, soon after it was produced it faced criticism from astronomers like al-Bukhārī, who found al-Maghribī's *Adwār al-anwār* to produce more accurate results.[40] Nevertheless, certain values for parameters in the *Zīj-i Ilkhānī* are not found in earlier *zījes* and do appear to derive from observations made at Maragha. These would be the observations made by al-Ṭūsī and the observatory staff – the *Zīj-i Ilkhānī* does not include values derived from any of al-Maghribī's observations. While the observation programs overlapped, they appear to have been distinct endeavors.[41]

It is notable that material from the *Zīj-i Ilkhānī* saw transmission into Greek, while that from the *Adwār al-anwār* did not. The latter had already been written for nearly twenty years by the time Chioniades (or any of his contemporaries) were in Tabriz in 1295, so the difference is not due to timing. But it is the *Zīj-i Ilkhānī* whose tables influenced parts of the *Persian Syntaxis*, and it is the *Zīj-i Ilkhānī* which is cited in the *Revised Canons*. The *Zīj-i Ilkhānī*, unlike the *Adwār al-anwār*, was available in

[38] In his *al-Zīj al-muḥaqqaq*; see Sayili, *The observatory in Islam*, p. 212–213 and Ragep, « New Light on Shams », p. 233–234.

[39] On the observations by al-Ṭūsī and staff, see Edward S. Kennedy, « A Survey of Islamic Astronomical Tables », *Transactions of the American Philosophical Society*, 46/2 (1956), p. 161–162, 169. On those by al-Maghribī, see e.g. Saliba, « An Observational Notebook of a Thirteenth-Century Astronomer » and Mozaffari, « Astronomical observations at the Maragha observatory in the 1260s–1270s ». On the observations by al-Bukhārī, see Mozaffari, Zotti, « The Observational Instruments at the Maragha Observatory after AD 1300 ». Ibid., p. 61–63 provides important updates to the narrative of Maragha Observatory's later history that had been presented in Sayili, *The observatory in Islam*.

[40] Sayili, *The observatory in Islam*, p. 214. On al-Bukhārī's criticisms, see Mozaffari, Zotti, « The Observational Instruments at the Maragha Observatory after AD 1300 », p. 64.

[41] The parameters which appear to derive from new observations include values for the longitude of solar apogee, one of the star tables, and the radius of the epicycle of Mars: see ibid., p. 56–57. On the absence of any of al-Maghribī's values, see Mozaffari, « Astronomical Observations at the Maragha Observatory in the 1260s–1270s », p. 595.

Persian, and perhaps this is one factor that encouraged the former's transmission and discouraged the latter's. But as will be seen below, al-Bukhārī was quite capable of teaching an Arabic treatise using the Persian language. His own work shows enough expertise with (and partiality to) the *Adwār al-anwār* that he might have been expected to have taught it.

Meanwhile, the *Zīj muḥaqqaq al-sulṭānī* would not be completed until after 1316 (based on its dedication to Abū Saʿīd Bahādur Khan), twenty years after the time in which al-Bukhārī was known to be teaching in Tabriz. It naturally would not have been among the materials transmitted into Greek in the 1290s. Al-Bukhārī did compile an earlier and preliminary version of this *zīj* for Sultan Öljaitü (*r*. 1304–1316), but this too was finished after his dated teaching activities.[42]
Instead, the *zījes* which saw translation into Greek – the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* – were ones which had been written over a century ago. The reasons for this might be better understood by considering the teaching activities which were ongoing in Maragha and Tabriz.[43]

V. *Students at Maragha and Tabriz*

Sources speak of numerous students at the Maragha Observatory. Many of these were attached to Naṣīr al-Dīn al-Ṭūsī, though their studies persisted after his death, as the report about Abaqa Khan funding them afterwards shows.[44]

Several of al-Ṭūsī's students are known by name: an example can be found in Quṭb al-Dīn al-Shīrāzī (d. 710/1311), who studied astronomy under him.[45] An impression of some of the texts al-Shīrāzī must have read under al-Ṭūsī can be gleaned from the student's subsequent works as well as from manuscript evidence. Al-Ṭūsī's edition of the *Almagest* was evidently one of these works studied, and the multiple early manuscript copies in al-Shīrāzī's hand or copied from his hand show

[42] See Mozaffari, Zotti, « The Observational Instruments at the Maragha Observatory after AD 1300 », p. 52. The dating for al-Bukhārī's teaching in Tabriz is dependent on the datable examples used in the Greek *Zīj al-ʿAlāʾī* and the *Revised Canons*, discussed below.

[43] A different possible explanation – that Shams al-Dīn al-Bukhārī intentionally did not teach Chioniades the most up-to-date astronomy – has been raised in Ragep, « New Light on Shams », p. 237, 243. The suggestion comes from Chrysokokkes's prologue to his *Persian Syntaxis*, where Chrysokokkes relates the claim that the Persians generally did not permit astronomy to be taught to foreigners due to an ancient story that the Romans would use astronomical knowledge acquired from the Persians to overthrow them. For the prologue, see Hermann Usener, *Ad historiam astronomiae symbola*, in *Kleine Schriften*, vol. III, B. G. Teubner, Leipzig 1914, p. 356–357.

[44] Sayili, *The observatory in Islam,* p. 219. Bar Hebraeus's *Chronography* reports al-Ṭūsī allotting stipends to the teachers and students under him during his lifetime: see Bar Hebraeus, *The Chronography of Abu'l-Faraj Bar Hebraeus*, p. 451.

[45] Ibn al-Fuwaṭī, *Talkhīṣ Majmaʿ al-Ādāb fī Muʿjam al-Alqāb*, vol. III, p. 440–441. While in Maragha, al-Shīrāzī also benefited from studies with the philosopher Najm al-Dīn al-Kātibī and the astronomer Muʾayyad al-Dīn al-ʿUrḍī.

that al-Shīrāzī contributed to the broader circulation of this edition after he left Maragha.[46] Al-Shīrāzī also studied the *Tadhkira* under his teacher: a colophon to a manuscript of the *Tadhkira* copied from al-Shīrāzī's own copy reports that the scholar had read it back to al-Ṭūsī. The *Tadhkira* proved to be an important influence on al-Shīrāzī's subsequent astronomical works.[47]

Among other intellectuals who spent time at Maragha and/or Tabriz, the most notable in terms of distance would be the Chinese astronomer Fao Munji – he is reported to have worked with al-Ṭūsī and is likely the source of the Chinese calendar which is found in al-Ṭūsī's *Zīj-i Ilkhānī* and al-Maghribī's *Adwār al-anwār*.[48] The Syriac scholar Gregory Bar Hebraeus made several visits to Maragha and appears to have engaged in astronomical study during these, as will be examined below. And of course, the Byzantine Gregory Chioniades came to Tabriz for the purpose of astronomical study. This is not an exhaustive list, and others whose names have been lost to the passage of time passed through the observatory as well.[49] Bar Hebraeus for instance mentions al-Ṭūsī's circles as comprising wise men from numerous countries.[50] A couple decades later the cosmopolitan nature of Ghāzān Khan's (*r.* 694–704/1295–1304) court was presented as a point of pride when Rashīd al-Dīn wrote that « philosophers, astronomers, scholars, and historians of all religions and nations – Cathay, Machin, India, Kashmir, Tibet, Uyghur, and other nations of Turks, Arabs, and Franks – are gathered in droves at our glorious court ».[51]

Some of the work at Maragha Observatory seems to have been accomplished with these broader audiences in mind. Notably, the *Zīj-i Ilkhānī* circulates with a preface which does not presume a Muslim audience. In it, the scholar takes the time to summarize the rise of Islam and explain such details as the fact that Muḥammad was a native of Mecca.[52] The *Zīj-i Ilkhānī* furthermore was first written in Persian, with the Arabic translation following after. This choice to use Persian –

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46 E.g. Chester Beatty Library, Ar. 3637 (691/1292), Nuruosmaniye Kütüphanesi 2941 (684/1285), and Bibliothèque nationale de France ar. 2485 (9th / 15th century).

47 On al-Shīrāzī's authorized copy of the *Tadhkira*, see Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy*, p. 72–73 and 78. On the influence of the *Tadhkira* on his works, see ibid., p. 57. On al-Ṭūsī's intentions for the *Tadhkira*'s usefulness to students and nonspecialists, see ibid., p. 37–38 and 56.

48 See Yoichi Isahaya, « History and Provenance of the 'Chinese' Calendar in the Zīj-i Ilkhānī », *Tarikh-e Elm*, 8 (2009), p. 20.

49 Note for example the Jewish astronomers Ibn al-Dāʿī al-Isrāʾīlī al-Irbīlī and Muntajab al-Dawla al-Isrāʾīlī al-Dahistānī, as mentioned in Yang, « Like Stars in the Sky », p. 395.

50 Bar Hebraeus, *The Chronography of Abu'l-Faraj Bar Hebraeus*, p. 451.

51 Translation from Rashīd al-Dīn, *Rashiduddin Fazlullah's Jamiʿu 't-tawārīkh: Compendium of Chronicles*, vol. I, trans. Wheeler M. Thackston, Harvard University Near Eastern Languages and Civilizations, Cambridge 1998, p. 6.

52 For the text of this preface, see Boyle, « The Longer Introduction », p. 244–254.

the *lingua franca* on the rise in the Ilkhanate – could also reflect a choice to make the treatise more accessible.

V.1. Bar Hebraeus as a Student of the Astral Sciences

One sample case of a non-Muslim scholar studying at Maragha is provided by Bar Hebraeus. This section will look at the Syriac scholar in more detail as an example of an individual who plausibly interacted with a range of subjects in the astral sciences at Maragha: spherical geometry, *hayʾa*, and *zījes.*

Bar Hebraeus pursued the astral sciences in several ways as part of his time in Maragha. Part of this involved work with the curriculum that proceeded from Euclid's *Elements*, through the Middle Books, and ended with Ptolemy's *Almagest* – all of which, as previously noted, had been edited by al-Ṭūsī. Bar Hebraeus writes that his first visit to Maragha in 1268 included work with Euclid and his second in 1273 with the *Almagest*.[53] Scholars have previously interpreted the Syriac verb used in connection with these texts to mean that Bar Hebraeus was involved in teaching or commenting on the *Elements* and the *Almagest* at the observatory. Takahashi has more recently put forth the suggestion that the verb in question should be interpreted as « studied ».[54]

Bar Hebraeus's writings furthermore demonstrate familiarity with al-Ṭūsī, though it is not certain whether he studied with him directly.[55] Regardless, the Syriac scholar worked with the astronomical curriculum mentioned above through al-Ṭūsī's editions of many of the texts. This is suggested by two manuscripts from this curriculum, one of which is plausibly connected with Bar Hebraeus and the other of which names him in an ownership note.

The first of these is London, British Library, Add. 23387, which contains al-Ṭūsī's edition of the *Elements*. Syriac and Garshuni notes written in a thirteenth-century Western *serto* appear in this manuscript. A recent study has compared the handwriting of these notes with a sample of Bar Hebraeus's own writing and argues it is plausible these notes come from the Syriac scholar.[56] The colophon on folio 216v declares that the manuscript in question was completed on 15 Rabīʿ II

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53 In his *Ecclesiastical Chronicle*: see Jean Baptiste Abbeloos, Thomas J. Lamy (eds.), *Gregorii Barhebraei Chronicon Ecclesiasticum*, vol. III, Maisonneuve-Peeters, Paris–Louvain 1877, p. 441–443.

54 Hidemi Takahashi, *Bar Hebraeus. A Bio-Bibliography*, Piscataway: Gorgias Press, 2005, p. 84. The verb is the Syriac « *šrā* » – past scholars have interpreted this to mean Bar Hebraeus taught or orally explained Euclid and the *Almagest*. Takahashi compares its use to that of its Arabic equivalent « *ḥalla* » which Bar Hebraeus uses to mean « study ». For an overview of these passages in Bar Hebraeus have been interpreted, see Pier Giorgio Borbone, « Marāgha mdittā arškitā: Syriac Christians in Marāgha under Mongol rule », *Egitto e Vicino Oriente*, 40 (2017), p. 125–126.

55 See Bar Hebraeus's comments on al-Ṭūsī in Bar Hebraeus, *The Chronography of Abu'l-Faraj Bar Hebraeus*, p. 451–452. See also the similarities between Bar Hebraeus's *Ascent of the Mind* and al-Ṭūsī's *hayʾa* treatises, discussed below.

56 Borbone, « Marāgha mdittā arškitā », p. 129–131.

656 (21 April 1258). It is not, therefore, a manuscript which was written during Bar Hebraeus's study of the *Elements* in Maragha, since this occurred ten years later. If the Syriac scholar used it during his time at the observatory, he acquired an existing codex for his studies.[57]

The second of these manuscripts is Istanbul, Hacı Selim Ağa 743, which contains al-Ṭūsī's edition of the Middle Books. A Syriac ownership note written in a Western *serto* states that the codex belonged to « Gregory, the lowly maphrian » with a year that corresponds to 1280–1 CE.[58] Several of the texts in the manuscript have dates of completion, ranging from 671–678 / 1272–1279.[59] It is unclear precisely when this manuscript came into Bar Hebraeus's possession. He may have acquired several initial treatises during his second visit to Maragha, and added to the compilation manuscript over time. He may have acquired it during one of his later visits to Maragha, such as the one in 1279. Or the manuscript may have come into his possession elsewhere. He certainly owned it by 1281 at the latest.[60]

Bar Hebraeus's study of this astronomical curriculum can also be seen in a third manuscript: Mashhad, Kitābkhāna-yi Markazī Astān-i Quds 5232. The codex's first folio is marked by an ownership statement that matches the ownership statement in the prior manuscript. Unlike the prior manuscript, however, the two Middle Books texts contained in this codex are the editions of al-Maghribī.[61]

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[57] The manuscript additionally would have had to have been copied outside of any circles associated with al-Ṭūsī, since in the colophon the scribe seems to have erroneously believed that al-Ṭūsī had already died.

[58] The ownership note appears on f. 136r; see Hidemi Takahashi, « L'astronomie syriaque à l'époque islamique », in Émilie Villey (ed.), *Les sciences en syriaque*, Geuthner, Paris 2014, p. 322. The contents of the manuscript are the fifteen treatises which comprised al-Ṭūsī's edition of the Middle Books: Theodosius's *Sphaerica*, Theodosius's *Nights and Days*, Autolycus's *Risings and Settings*, Hypsicles's *Anaphoricus*, Aristarchus's *Sizes and Distances*, pseudo-Archimedes's *Lemmata*, Thabit's *Data*, the Banu Musa's *Book of Knowledge*, Archimedes's *Sphere and Cylinder*, Menelaus's *Spherics*, Autolycus's *On the Moving Sphere*, Euclid's *Data*, Theodosius's *On Habitations*, Euclid's *Optics*, and Euclid's *Phaenomena*.

[59] Euclid's *Data*: 14 Rabīʿ II 671 H, Euclid's *Optics*: Rabīʿ II 671 H, Autolycus's *Moving Sphere*: 4 Muḥarram 672 H, Menelaus's *Spherics*: 9 Jumadā 678 H, Theodosius *On Habitations*: 671 H. See Max Krause, « Stambuler Handschriften islamischer Mathematiker », *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik, Abteilung B, Studien*, 3 (1936), p. 499–504.

[60] For his visit in 1279, see Bar Hebraeus, *Gregorii Barhebraei Chronicon Ecclesiasticum*, vol. III, p. 447–450. For the suggestion that Bar Hebraeus personally transcribed the Arabic of the editions of Archimedes in this manuscript, see Aydin Sayili, « Khwāja Naṣīr-i Ṭūsī wa raṣadkhāna-i Marāgha », *Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi*, 14/1-2 (1956), p. 11 and Borbone, « Marāgha mdittā arškitā », p. 130–131.

[61] For a description of this manuscript, see Sajjad Nikfahm-Khubravan and Osama Eshera, « The Five Arabic Revisions of Autolycus' On the Moving Sphere (Proposition VII) », *Tarikh-e Elm*, 16/2 (2019), p. 48.

There is further evidence for Bar Hebraeus having studied the *Almagest* at Maragha, though not in the recension by al-Ṭūsī. Kâtip Çelebi reports that the Syriac scholar requested a new edition of the *Almagest* from al-Maghribī.[62]

Outside of the above Greek geometrical and astronomical treatises, hints of other texts Bar Hebraeus may have encountered at Maragha are offered by the Syriac scholar's own works. His *Ascent of the Mind*, completed in 1279, is a handbook of astronomy that bears similarity to al-Ṭūsī's *hayʾa* treatises. Some scholars have pointed to al-Ṭūsī's *Tadhkira* as its model based on its agreements in structure and values. More recently, al-Ṭūsī's *Zubdat al-idrāk fī hayʾat al-aflāk* (undated) has been raised as a possible model for Bar Hebraeus's text.[63] The *Zubdat al-idrāk* is a short and simplified *hayʾa* treatise that is intended to epitomize works on the subject.[64] While this shorter work appears to have had little lasting influence compared to al-Ṭūsī's other treatises, it is possible that it was being used as an elementary teaching text during Bar Hebraeus's time in Maragha.

Lastly, Bar Hebraeus reports that he wrote a book on *zījes* for beginners in Syriac.[65] This work has not been found, so it is not certain which *zījes* Bar Hebraeus may have drawn upon for it. In any case, the (former) existence of this treatise raises the possibility that his astronomical studies at Maragha included various *zīj* texts.

V.2. Astronomical Texts Taught in Maragha

The example of Bar Hebraeus suggests a range of astronomical texts received study in Maragha. Established teaching texts like the *Elements*, Middle Books, and *Almagest* formed one component. Newer works formed another component, as is seen by Bar Hebraeus's familiarity with the *Tadhkira* or perhaps the *Zubdat al-idrāk*.

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62 Kâtip Çelebi, *Lexicon bibliographicum et encyclopaedicum*, p. 387, 389. There exists a *Talkhīṣ al-majisṭī* by al-Maghribī that is extant: see Saliba, « An Observational Notebook of a Thirteenth-Century Astronomer ». In the preface to this al-Maghribī also mentions a summary of the *Almagest* he had produced titled *Khulāṣat al-majisṭī*, which has not been discovered. It is not clear if either of these treatises are the edition produced for Bar Hebraeus.

63 For its relation to the *Tadhkira*, see François Nau, *Le livre de l'ascension de l'esprit sur la forme du ciel et de la terre. Cours d'astronomie rédigé en 1279 par Grégoire Aboulfarag, dit Bar-Hebraeus*, pt. II, Librairie Émile Bouillon, Paris 1899, p. vii. For the possible connection with the *Zubdat*, see Hidemi Takahashi, « The Mathematical Sciences in Syriac: From Sergius of Resh'Aina and Severus Sebokht to Barhebraeus and Patriarch Ni'matallah », *Annals of Science*, 68/4 (2011), p. 486–487.

64 Al-Ṭūsī may have intended the *Zubdat al-idrāk* as an abridgement of his *Tadhkira*, but the former text has received very little study and so its relationship to the scholar's other treatises is unclear: see Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy*, p. 66–67. One difference between the *Zubdat al-idrāk* and the *Tadhkira* is the former's avoidance of criticisms of the Ptolemaic system. The idea that Bar Hebraeus preferred it as a model because of this closer adherence to Ptolemy has been raised by Takahashi, « The Mathematical Sciences in Syriac » p. 487.

65 Bar Hebraeus, *The Chronography of Abu'l-Faraj Bar Hebraeus*, p. xxxiii.

Unfortunately it is not clear whether Bar Hebraeus's study of *zīj* texts comprised older established *zījes* or new products of the observatory.

While the *Elements*, Middle Books, and *Almagest* were indeed long-established teaching texts in the Islamic world, it should be emphasized that at Maragha they were taught through new editions: those of al-Ṭūsī and al-Maghribī. The above has already noted al-Ṭūsī's editions and al-Maghribī's edition of the *Almagest*. Like his colleague, al-Maghribī's editing project extended to other texts in the curriculum as well. He produced editions of the *Elements* and of at least three of the Middle Books texts.[66]

These texts had received study in the Islamicate world since their translation from Greek into Arabic in the ninth century. The separate editorial projects of al-Ṭūsī and al-Maghribī both aimed to produce versions with increased pedagogical usefulness. In the introduction to his edition of the *Almagest*, al-Ṭūsī writes that he had deemed past editions and summaries of the *Almagest* insufficient. He aimed to produce a work that preserved all the component parts of Ptolemy's text but in a more concise and clear Arabic style. He allowed additions to the work where such additions would clarify mathematical difficulties or simplify a convoluted argument, but took care to indicate what he had added to the text versus what was original. The introduction to his edition of the *Elements* lays out a similar set of goals as the introduction of the *Almagest* did.[67] While al-Ṭūsī does not write so explicitly about his goals for his editions of the Middle Books, these texts show the same interest in conciseness and the same allowance for mathematically useful

[66] For the *Elements* see discussion in Abdelhamid I. Sabra, « Simplicius's Proof of Euclid's Parallels Postulate », *Journal of the Warburg and Courtauld Institutes*, 32 (1969), p. 13–18. On al-Maghribī's edition of Theodosius's *Sphaerica*, see Bernard Carra de Vaux, « Notice sur deux manuscrits arabes: Remaniement des *sphériques* de Théodose par Yahia ibn Muhammad ibn Abi Schukr Almaghrabi Alandalusi », *Journal Asiatique*, 17 (1891), p. 287–295. Al-Maghribī's edition of Menelaus's *Spherics* is noted by Roshdi Rashed and Athanase Papadopoulos, *Menelaus's ›Spherics‹: Early Translation and al-Māhānī / al-Harawī's Version*, Walter de Gruyter GmbH, Berlin 2017, p. 15. His edition of Autolycus's *On the Moving Sphere* is noted by Nikfahm-Khubravan, Eshera, « The Five Arabic Revisions of Autolycus's On the Moving Sphere (Proposition VII) ».

[67] For the introduction to al-Ṭūsī's edition of the *Almagest*, see George Saliba, « The Role of the Almagest Commentaries in Medieval Arabic Astronomy: a Preliminary survey of Ṭūsī's Redaction of Ptolemy's Almagest », *Archives internationales d'histoire des sciences*, 37 (1987), p. 5–6. For the introduction to his edition of the *Elements*, see for example British Library Add MS 23387, fol. 2v. Note that al-Ṭūsī's edition of the Elements has not been edited or printed: the text printed in *Kitāb Taḥrīr uṣūl li-Ūqlīdis*, Rome: Typographia Medicea, 1594 has been shown to be not by al-Ṭūsī, but rather by an unnamed thirteenth-century individual. For more on this, see Gregg De Young, « Further adventures of the Rome 1594 Arabic redaction of Euclid's Elements », *Archive for History of Exact Sciences*, 66 (2012), p. 265–294.

additions.[68] Al-Maghribī expresses similar goals in the introduction to his edition of the *Elements*.[69]

These, however, were not the kinds of teaching texts that would be translated into Greek. It is natural that a Byzantine student would not have felt a need to retranslate originally Greek texts, even in new editions or adaptions.[70]

Meanwhile, the *Tadhkira* and associated *hay'a* texts also appear to have numbered among the texts taught at Maragha. The evidence from al-Shīrāzī shows that the *Tadhkira* was definitely taught; the subsequent influence of the *Tadhkira* shows that it was read widely. That Bar Hebraeus possibly drew from the *Zubdat al-idrāk* rather than from the *Tadhkira* would suggest that *hay'a* texts besides the *Tadhkira* remained available and continued to be studied, despite the latter's significant usage.

In the case of *zījes*, Maragha did see the production of at least one intended specifically for students. The manuscript Cairo, Egyptian National Library, MM 188 preserves a *zīj* titled *ʿUmdat al-ḥāsib wa-ghunyat al-ṭālib* (*c.* 1262). This text appears to have been compiled by one of al-Maghribī's students during studies with the astronomer. The prologue names al-Maghribī as the teacher and states that the

[68] The conciseness of al-Ṭūsī's editions is readily apparent when they are compared to the corresponding earlier Arabic translations. The sentence structure of the latter frequently took care to replicate what was found in the Greek with all its verbosity and repetitions. For al-Ṭūsī's editions of the Middle Books, a print edition is available in *Majmūʿ al-rasā'il*, vol. I and II, Hyderabad-Deccan, 1939-40. These texts have not been critically edited in full. Compare with the earlier Arabic translations and revisions, several of which have been critically edited: Nathan Sidoli, Yoichi Isahaya, *Thābit ibn Qurra's Restoration of Euclid's Data: Text, Translation, Commentary*, Springer, Cham 2018; Elaheh Kheirandish, *The Arabic Version of Euclid's Optics (Kitāb Uqlīdis fī Ikhtilāf al-manāẓir)*, Springer Science+Business Media, New York 1999; Vittorio De Falco, Max Krause, Otto Neugebauer, *Hypsikles Die Aufgangszeiten der Gestirne*, Vandenhoeck & Ruprecht, Göttingen 1966; Paul Kunitzsch, Richard Lorch, *Theodosius. De habitationibus: Arabic und Medieval Latin Translations*, Verlag der Bayerischen Akademie der Wissenschaften, Munich 2010; Paul Kunitzsch, Richard Lorch, *Sphaerica: Arabic and Medieval Latin Translations*, Franz Steiner Verlag, Stuttgart 2010; and Paul Kunitzsch, Richard Lorch, « Theodosius, De diebus et noctibus », *Suhayl*, 10 (2011), p. 9–46.

[69] See Sabra, « Simplicius's Proof of Euclid's Parallels Postulate », p. 14–15.

[70] It is possible, however, that the study and production of such texts in Maragha encouraged a renewed interest in their study and production in the Byzantine Empire. Later Byzantine scholars such as Theodore Metochites (d. 1332) turn again to treatises which had once formed part of the Little Astronomy (i.e. the late antique Greek predecessor to the Middle Books). Metochites chooses these works as part of a syllabus to prepare himself for the production of an epitome of the *Almagest*. See his comments in his *Introduction to Astronomy* I.1.32: Börje Bydén, *Theodore Metochites' Stoicheiosis Astronomike and the Study of Natural Philosophy and Mathematics in Early Palaiologan Byzantium*, Acta Universitatis Gothoburgensis, Göteborg 2003, p. 436–437. Whether such developments may have been influenced by contemporary work in Persia requires further study.

text is intended to be a benefit to students and beginners. It presents material from a number of different sources.[71]

VI. *Greek Translations out of Maragha and Tabriz*

VI.1. The Translators: Gregory Chioniades and Contemporaries

The narrative of Gregory Chioniades's studies in Tabriz comes largely from the prologue to the *Persian Syntaxis* by George Chrysokokkes (*fl.* 1350).[72] The latter astronomer notes his own studies in Persian astronomy under a teacher named Manuel in the city of Trebizond and he then transmits an account from Manuel on how this material came to be translated into Greek. In this narrative, Gregory Chioniades was educated in the sciences in Constantinople and then traveled to Persia to further his learning. He was particularly interested in a science that would aid him in the practice of medicine.[73] Chioniades travelled through Trebizond and began studies in an unnamed Persian city. He was initially barred from learning the astral sciences because of a prohibition against teaching the subject to Romans, but was able to acquire an exemption. He subsequently returned to Trebizond with many astronomical books, which he translated into Greek. Chrysokokkes later used these works in the composition of his *Persian Syntaxis*.

Chioniades's own works offer further details to this narrative. His letters make it clear that he travelled through Trebizond and that he spent time at the Ilkhanate capital, Tabriz, as the Orthodox archbishop there.[74] Tabriz would therefore seem to be the location in which Chioniades learned the astral sciences in Persian. His long stay in the Ilkhanate is also seen in the fact that Chioniades found it necessary to write a *Profession of Faith* (Ὁμολογία τοῦ ἰατροσοφιστοῦ Χιονιάδου) (*c.* 1305) defending himself against accusations of heterodoxy that arose because of his time there.[75] There are additionally scholia and diagrams which Chioniades added to a

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71 Mozaffari, « Astronomical observations at the Maragha observatory in the 1260s-1270s », p. 594–595.

72 For the prologue, see Usener, *Ad historiam astronomiae symbola*, p. 356–357. It has been translated and discussed in e.g. Mercier, « The Greek 'Persian Syntaxis' and the Zīj-i Ikhān », p. 35–36 and Anne Tihon, « Astrological Promenade in Byzantium in the Early Palaiologan Period », in Paul Magdalino, Maria Mavroudi (eds.), *The Occult Sciences in Byzantium*, La Pomme d'or, Geneva 2006, p. 274–275.

73 Tihon suggests this to be for the purpose of medical astrology: see Tihon, « Astrological Promenade », p. 274–275.

74 Jean B. Papadopoulos, Γρηγορίου Χιονιάδου τοῦ ἀστρονόμου Ἐπιστολαί, Ἐπιστημονικὴ Ἐπετηρὶς τῆς Φιλοσοφικῆς Σχολῆς τοῦ Πανεπιστημίου Θεσσαλονικῆς, vol. I, 1927, p. 151–205. The biographical details from these letters are summarized in Leendert Westerink, « La profession de foi de Grégoire Chioniadès ». *Revue des études byzantines*, 38 (1980), p. 235–236.

75 See Westerink, « La profession de foi », p. 236 and 243–245.

manuscript of John of Damascus's *Fountain of Knowledge* that show his knowledge of the Islamic astral sciences.[76]

Such is what can be gathered from material from Chioniades or which names him directly. Meanwhile, Chioniades's association with Shams al-Din al-Bukhārī and the attribution of particular translations to the Greek scholar have been inferred based on what is found in several fourteenth-century Greek manuscripts.[77] These manuscripts contain the Greek works which were presented above: translations of the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī*, texts attributed to Shams al-Bukhārī, and other astronomical material. Pingree argued that since the *Persian Syntaxis* can be seen to be drawing from the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī*, the Greek translations found in the manuscripts should be identified with the translations of Persian astronomy which Chrysokokkes says he used in the *Persian Syntaxis* and which he attributes to Chioniades. These translations, furthermore, were made as a result of astronomical study in Tabriz, where Chioniades is known to have been located.[78] Shams al-Bukhārī – identified with Shams al-Dīn Muḥammad ibn ʿAlī Khwāja al-Wābkanawī, as discussed above – is therefore taken to have been Chioniades's teacher because the Greek translations of the *Zīj al-ʿAlāʾī*, the *Revised Canons*, and the *Zīj al-Sanjarī* all mention material coming from the oral teaching of Shams (al-Bukhārī).[79]

Granted, the attributions of the translations in these manuscripts to Chioniades is not definitive – Chioniades is nowhere mentioned in the relevant manuscript

[76] These marginalia are found in Chioniades's own hand in the manuscript New York, Columbia University, Smith Western Add. 10 (manuscript completed in 1296, with subsequent annotations in 1301–2). They are discussed briefly in Pingree, *Astronomical Works of Gregory Chioniades*, p. 18–21. A more detailed examination is offered by Alexandre M. Roberts, « Byzantine-Islamic Scientific Culture in the Astronomical Diagrams of Chioniades on John of Damascus », in Jeffrey Hamburger, David Roxburgh, Linda Safran (eds.), *The Diagram as Paradigm: Cross-Cultural Approaches*, Dumbarton Oaks Research Library and Collection, Washington, DC (forthcoming).

[77] The manuscripts in question are Rome, Vaticanus graecus 211 (before 1308 CE), Florence, Biblioteca Medicea Laurenziana, Plut. 28.17 (1323 CE), and Rome, Vaticanus graecus 1058 (mid 14th cent.). They are described in Pingree, *The Astronomical Works of Gregory Chioniades*, p. 23–28. Pingree's descriptions are followed by Leichter, « The Zīj al-Sanjarī of Gregory Chioniades », p. 12–13 and Paschos, Sotiroudis, *The Schemata of the Stars*, p. 12–13.

[78] Pingree, « Gregory Chioniades and Palaeologan Astronomy », p. 142. As noted above, Mercier disagreed with Pingree and argued that the source of the *Persian Syntaxis* was rather the *Zīj-i Ikhānī*: Mercier, « The Greek 'Persian Syntaxis' and the Zīj-i Ikhān », p. 37–38. Pingree subsequently responded to Mercier's argument in Pingree, « In Defence of Gregory Chioniades », p. 436–438. While material from the *Zīj-i Ikhānī* is present in the *Persian Syntaxis*, Pingree maintained that Chrysokokkes's treatise drew on the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* as well.

[79] See Pingree, *The Astronomical Works of Gregory Chioniades*, p. 36: « ἀπὸ φωνῆς τοίνυν τοῦ Σὰμψ Πουχάρης »; p. 306: « ἀπὸ φωνῆς τοῦ Σὰμψ Μπουχαρῆ »; and Leichter, « The Zīj al-Sanjarī of Gregory Chioniades », p. 564: « ἀπὸ φωνῆς τοῦ Σάμψ ».

texts, let alone as author or translator.[80] But the scholar was undoubtedly involved in the transmission of Persian material, as his own notes and Chrysokokkes suggest. For the translations of the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* in particular, the preponderance of evidence does point to him as the most likely translator. With that said, he may not have been the only Byzantine scholar active in Tabriz. Other Greek-Arabic contacts in this period are suggested by a work by Maximos Planoudes, which was derived from an earlier Byzantine treatise on Indian numerals but which – unlike its source – used numerals in the same form as those used in Persian.[81] While it is plausible that among Chioniades's contemporaries there numbered further translators and adaptors working with Persian material, details on these individuals are unfortunately scarce.[82]

VI.2 The Greek Translations and Adaptions

The *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* appear to have been the subject of study by their translator in the last decade of the thirteenth century. The translation of the *Zīj al-ʿAlāʾī* can be roughly dated based on the examples used in the text, which are largely drawn from the years 1295 and 1296. Examples are also set in Tabriz, indicating the location of study as well.[83] That the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* were translated by the same person is suggested not only by their grouping in manuscripts but also their shared technical terminology, including shared

[80] ANNE TIHON, « Les tables astronomiques persane à Constantinople dans la première moitié du XIVe siècle », *Byzantion*, 57 (1987), p. 474–475. Tihon also compares the handwriting of Chioniades, known from New York, Columbia University, Smith Western Add. 10, with the hand responsible for texts in the above manuscripts written at the end of the thirteenth century and sees no similarities. She additionally suggests that the variations in the spellings of e.g. Persian names and the value zero would imply multiple individuals behind the texts in Vat. gr. 211, Laur. Plut. 28.17, and Vat. gr. 1058.

[81] For comments on these other Persian-Greek contacts, especially that of Planoudes, see BYDÉN, *Theodore Metochites' Stoicheiosis Astronomike*, p. 241–242, 261–262. See more recently ANNE-LAURENCE CAUDANO, « Astronomy and Astrology », in STAVROS LAZARIS (ed.), *A Companion to Byzantine Science*, Brill, Leiden 2020, p. 222–223, who notes that multiple translators may have been at work in this period besides Chioniades.

[82] As noted above, Rashīd al-Dīn offered laudatory comments on the range of intellectuals attracted to Ghāzān Khan's court. It is worthwhile to note the existence of a question and answer text by Rashīd al-Dīn, in which he answered the questions of a Frank physician; see ZEKI VELIDI TOGAN, « İlhanlılarla Bizans Arasındaki Kültür Münasebetlerine Ait Bir Vesika » (« A Document Concerning Cultural Relation between the İlkhanide and Byzantiens »), *İslâm Tetkikleri Enstitüsü Dergisi*, 3 (1959–1960). This may have been one of Chioniades's unknown contemporaries. Alternatively, Chioniades did travel to Tabriz with interests in medicine: ibid., p. 15, notes the possibility that this Frank physician was Chioniades himself.

[83] For an overview, see PINGREE, *The Astronomical Works of Gregory Chioniades*, p. 17. Chapters 32–35 use an example from an earlier year, 1293, because 5 July 1293 was the date of a solar eclipse. Conversely, the examples for chapters 38–60 are largely from al-Fahhād's original text.

incorrect technical terminology.[84] As noted above, the texts of both state that they come from the teachings of Shams al-Bukhārī, as does that of the *Revised Canons*, whose examples largely use the year 1296.[85]

The vocabulary of the *Zīj al-ʿAlāʾī*, *On the Genethialogical Computation*, and the *Revised Canons* makes it clear that this teacher dictated these texts to his student in Persian. The Arabo-Greek translation of the *Zīj al-ʿAlāʾī* therefore had an intermediary language. The translation of the *Zīj al-Sanjarī* conversely does not seem to have been translated via Persian. It may have benefitted from the use of an Arabic-Greek dictionary, or was simply produced at a point in time when the translator had improved his knowledge of Arabic.[86]

It would appear that these two *zījes* were ones which had already been established as useful teaching texts. They were not the product of recent research at the Maragha Observatory, but this is not surprising: the most recent zijes were not necessarily the ones best suited for a student early in his studies. It is also known that al-Bukhārī was at the time involved in making observations to test the results of both the *Zīj-i Ilkhānī* and the *Adwār al-anwār* — thus, neither of these *zījes* had yet been tested and found useful as fully as the two earlier *zījes* being discussed had been. The *Zīj al-ʿAlāʾī* had already seen significant usage and influenced several *zījes* that came after it.[87] Meanwhile the version of the *Zīj al-Sanjarī* that was translated into Greek was an epitome of the original *zīj* – this abbreviated version may have been selected as particularly handy for a student. It should be noted that while these were not new *zījes*, they still received updates, as can be seen in the contemporary examples that replaced most of al-Fahhād's original examples in the *Zīj al-ʿAlāʾī*.

The *Revised Canons*, however, show that by 1296 the student had indeed worked with one of the treatises that came out of Maragha Observatory: the *Zīj-i Ilkhānī*. The transmission of material from this treatise into Greek is also shown by Chrysokokkes's *Persian Syntaxis*, which makes use of it alongside material from the

84 Leichter, « The Zīj al-Sanjarī of Gregory Chioniades », p. 10–11.

85 See the dates given in the computational commentary in Pingree, *The Astronomical Works of Gregory Chioniades*, p. 386–394. An exception is in chapter 17, which concerns a lunar eclipse that occurred on 30 May 1295.

86 On the *Zīj al-ʿAlāʾī*, *On the Genethialogical Computation*, and the *Revised Canons*, see ibid., p. 16–17. Pingree points to the regular absence of the Arabic « al- » and presence of the Persian « -i » in transliterated terms, as well as the non-technical Persian terms in the texts. On the *Zīj al-Sanjarī*, see Leichter, « The Zīj al-Sanjarī of Gregory Chioniades », p. 11–12. Leichter notes the near absence of Persian terms in this text and the significantly fewer transliterations of Arabic technical terms when compared to the *Zīj al-ʿAlāʾī*.

87 Pingree, *The Astronomical Works of Gregory Chioniades*, p. 7–8. Material from it furthermore saw transmission into Hebrew derivatives.

Zīj al-ʿAlāʾī and the *Zīj al-Sanjarī*.[88] The choice of al-Ṭūsī's *zīj* for study at this stage rather than al-Maghribī's may have been influenced by language: the former was available in Persian while the latter was in Arabic. As noted above, al-Ṭūsī's treatise also may have been viewed as more accessible to a non-Muslim audience, potentially influencing its selection. However, it is not possible to rule out its selection being simply an accident of timing: al-Bukhārī's own work at the time could have happened to focus more on testing the methods of the *Zīj-i Ilkhānī*, and so this was the *zīj* which he taught.

Meanwhile, if the *Schemata of the Stars* is indeed mostly a translation of the *Risāla-yi Muʿīniyya* as Ragep contends, this would fit with what is seen above: a Greek student who is to some extent more accustomed to Persian than to Arabic. While al-Ṭūsī's Arabic *Tadhkira* updated and superseded his earlier Persian *Risāla-yi Muʿīniyya*, this does not imply that the former text made the latter unavailable. As discussed, Bar Hebraeus may have worked with still another *hay'a* treatise by al-Ṭūsī in Maragha, the *Zubdat al-idrāk*. While the *Tadhkira* proved quite influential, al-Ṭūsī's other treatises on the subject appear to have remained in use alongside it. As for the *Schemata of the Stars*, it is notable that it makes very few references to Persian or Arabic terms.[89] If it is to be connected with Chioniades, then (similarly to the translation of the *Zīj al-Sanjarī*) it would have been written at a later stage when he was more experienced with the language.

The translation of the work on the astrolabe came from an Arabic or Persian original.[90] The text shows several differences from the treatises above. It is not grouped with the rest in all three of the relevant manuscripts, appearing instead only in Vaticanus graecus 1058, which is later and contains a larger mixture of texts.[91] Its translator does not go unrecorded but rather names himself in the text. In the preface, an individual who gives his name as Σιὰμψ τοῦ Πέρσου presents the translation to accompany the gift of an elaborate astrolabe to the Byzantine emperor Andronicus Palaeologus – most likely Andronicus II (*r.* 1282–1328). This individual was plausibly Shams al-Dīn al-Bukhārī.[92] This translation seems to have

[88] Unfortunately, although Chrysokokkes's prologue states that he is using Greek translations of Persian material and presumably had a translation of the *Zīj-i Ilkhānī* in some form at hand, this source has not been found.

[89] Paschos, Sotiroudis, *The Schemata of the Stars*, p. 14.

[90] A summary of transliterated terms is available in Anne Tihon, « Traités byzantins sur l'astrolabe », *Physis*, 32 (1995), p. 334–335. A couple show the Persian « -i », though this small sample is not enough evidence to say definitively that the original text was Persian instead of Arabic, especially when the translator himself was Persian.

[91] This however is not the only manuscript which contains this translation of the work on the astrolabe: see e.g. the manuscripts given in ibid., p. 333.

[92] It should be noted that some doubts have been raised regarding this attribution by ibid., p. 333. Tihon notes that the earliest manuscripts date from the mid fourteenth century and that the

been exchanged as part of diplomatic contacts between the Byzantines and the Ilkhānids – it is undoubtedly an outlier among the other translations in terms of motivations and usage.

VII. *Conclusion*

The Arabo- and Perso-Greek translations and adaptions attributed to Gregory Chioniades have long been acknowledged to come from study in Persia, thanks both to the narrative account of astronomical transmission presented by Chrysokokkes and to the acknowledgement in several of the translated texts themselves of the student's teacher. This paper has delved into what is known from the Islamicate sources about astronomical study in Persian centers for the subject at the end of the thirteenth century.

The Maragha Observatory and its contributions to the astral sciences loom large in this period. It has been shown that the astronomers whose efforts were producing these new results were often the same astronomers who were involved in teaching the subject. Indeed, texts that were output from work at Maragha did feature in what was studied by students. One, however, should not focus overmuch on these new products when considering the broader picture of astronomical study in this period, which relied largely on texts that were more established. The curriculum of spherical geometry — the *Elements*, the Middle Books, and the *Almagest* — serves as a more dramatic example, since these were texts with a tradition of study in Arabic going back to their translation out of Greek in the ninth century. Regardless, it should similarly not be surprising to see al-Ṭūsī's *Zīj-i Ilkhānī* drawing on the *zījes* of Ibn Yūnus and Ibn al-Aʿlam, nor to see the *Zīj al-ʿAlāʾī* and the *Zīj al-Sanjarī* being taught in 1290s Tabriz, more than a century after their composition. The ongoing observation program by al-Bukhārī to test the results of the *Zīj-i Ilkhānī* and the *Adwār al-anwār* makes it clear that these *zījes* were still the subject of active work and confirmation. They were not texts already tested and proven, and as such may not have been a first choice for teaching purposes, especially more preliminary ones.

Those of the discussed translations and adaptions into Greek that came out of didactic contexts had their sources in this melding of old and new texts. The libraries of Maragha and Tabriz amassed established works in the astral sciences, the teachers in these centers had already produced their own editions of older texts and composed many of their own contributions, and those same teachers

dedicatee could have been Andronicus III (*r.* 1328–1341) rather than Andronicus II. She also notes that the spelling Σιάμψ in this treatise differs from the spelling Σάμψ found in the translated zïjes. FISHER, « Arabs, Latins, and Persians bearing gifts », p. 169–170 concludes that the attribution to Shams al-Dīn al-Bukhārī is plausible, though not definitive.

were astronomers engaging in observation programs and publishing their new results.

From this available corpus, then, the specific selection of materials that received study by the Byzantine student or students appears to have been motivated by their particular needs. Much of the cluster of translations and adaptions, taken together, speak to a student who acquired increased skill with Persian and Arabic over time, but for whom Persian was perhaps the more familiar language. This could explain the choice of al-Ṭūsī's *zīj* over al-Maghribī's, and it could similarly support the *Schemata of the Stars*' source in the *Risāla-yi Muʿīniyya* rather than the Arabic *Tadhkira*. While certain works which were used or produced in Maragha and Tabriz may have proved more influential over time, understanding the fuller picture of education in the astral sciences in these centers is necessary when exploring these more individually motivated transmissions of knowledge.

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