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# Global History: Understanding Islamic Astronomy

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This study presents a new conceptualization of the history of Islamic astronomy. Islamic history is an embedded global cultural phenomenon and will be analyzed at different levels: a) the history of institutional aspects (observatories, including buildings), b) instruments, c) manuscripts, and d) scholars. This phenomenon will be analyzed as a multi-lingual phenomenon with Arabic as the language of sciences as a starting point. Although this is not a study of a geographical region in a narrow sense, it is a historical note on the entanglement of research written in Arabic, Persian and other languages and contextualized in a framework reaching geographically far beyond the confines of the Islamic world and being part of global history.[1]

**Keywords**: Islamic Astronomy, Observatories, Samarqand, History of Sciences, Global History

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## Introduction

The overarching structure of the urban-nomadic area setting the stage for the unfolding of astronomical knowledge can be described as Persianate[2] to define the cultural-linguistic space. The Persianate world developed into a lingua franca of diplomacy, education and learning in a region that stretched from China to the Balkans and was made possible by the *Pax Mongolica*. At the same time, we have to understand the movement of ideas, tools and institutions as part of the Silk Roads.[3]

The Islamic contribution to scientific knowledge is to be understood as part of the discourses framed in the dominant Persian language cultural production of the post-classical[4] time of the Islamic world embedded in a global network stretching from East Asia to Western Europe. Talking about Arabic or Persian does not refer to ethnicized, homogenous identities in a modern sense, but to a multi-faceted ambiguous[5] world with its multi-layered discourses expressed in different languages according to different situations.

For the study of the institutional aspects of the history of astronomy, I will take up Bruno Latour's Actor-Network-Theory that had a great impact on global history[6] and on the modern discussion on the philosophy[7] and history of science. Taking into account that the institutional aspects of sciences like laboratories,[8] instruments and buildings[9] are now understood as an essential part of scientific knowledge, it may not be not too daring to

2 For an exploration of this concept far beyond the initial idea of Hodgson, see N. Green, *The Persianate World: The Frontiers of a Eurasian Lingua Franca* (Oakland, CA: University of California Press, 2019). Cf. B. G. Fragner, *Die "Persophonie": Regionalität, Identität und Sprachkontakt in der Geschichte Asiens* (Berlin: Das Arabische Buch, 1999) for another concept well established in Iranian Studies.

3 In a comparative view, we may look at other artefacts like maps [see the contributions in P. Forêt and A. Kaplony, eds., *The Journey of Maps and Images on the Silk Road* (Leiden: Brill, 2008)]. Interestingly the *Silk Road Encyclopedia* (S. Jeong, *The Silk Road Encyclopedia*, Irvine, CA: Seoul Selection, 2016) only passingly mentions astronomy. Referring to Europe seems possible if we understand the Silk Roads as a paradigm for global history – even if some Eurocentric sensitivities may be touched.

4 For this period referring to Central Asia, see F. Griffel, *Den Islam Denken: Versuch, eine Religion zu Verstehen* (Kitzingen: Reclam, 2018).

5 For the idea of ambiguity in the Arab and Islamic world, see T. Bauer, *Die Kultur der Ambiguität* (Berlin: Insel, 2011).

6 D. Gerstenberger and J. Glasman, *Techniken der Globalisierung: Globalgeschichte Meets Akteur-Netzwerk-Theorie* (Bielefeld: Transcript Verlag, 2016).

7 For the relationship between Islamic philosophy and astronomy and the reaction against the critique of the Ash'arite theologians see (referring to Ibn Sina) F. J. Rageb, "The Khilāṣ kayfiyyat tarkīb al-aflāk of al-Jūzjānī: A Preliminary Description of Its Avicennian Themes," in *Avicenna and His Legacy: A Golden Age of Science and Philosophy*, ed. Y. T. Langermann (Turnhout: Brepols, 2009), 301-306; and R. G. Morrison, "Falsafa and Astronomy after Avicenna: An Evolving Relationship," in *Avicenna and His Legacy: A Golden Age of Science and Philosophy*, ed. Y. T. Langermann (Turnhout: Brepols, 2009), 307-326.

8 B. Latour and S. Woolgar, *Laboratory Life: The Contruction of Scientific Facts* (Princeton, NJ: Princeton University Press, 1979).

9 H. J. Rheinberger, *On Historicizing Epistemology: An Essay* (Stanford, CA: Stanford University Press, 2010).

start with a hypothesis that observatories[10] and a sound understanding of the importance of observatories are a good starting point for our analysis of the history of astronomy in the Islamic world and beyond.[11] That is, we will move from the Arabic language/Arab world to the Islamic world and then to a global level and back again.

## Spaces

The movement from the Persianate world, linguistically speaking, including many ethnically diverse writers using Arabic and Persian as common languages of intellectual discourse in different contexts, to the global world, technically speaking of astronomic discourses and artifacts, be it buildings, instruments or manuscripts, and to a transcendent sphere that affects the Arabic language discourses (and some Persian) on natural philosophy reminds us of the assemblages and the smooth and striated space Deleuze and Guattari talk about in their *Thousand Plateaus* and "the interaction of the two kinds of space."[12] This leads us to "the idea that the smooth and the striated are two tendencies toward which every assemblage tends, and that any given assemblage is a ratio of these tendencies."[13] We will follow this double-faced process, this movement from the smooth to the striated and back again during this study.

Since the philosophy of Deleuze and Guattari[14] is one of the most important philosophical approaches of the 20th and 21st centuries, but not very well known yet, we will give a short outline of the Deleuzian understanding of these spaces. In the writings of Deleuze, space is measured according to degrees of smoothness and striation. A "smooth space" is "a space that is without border or distinction that would privilege one site or place over another," whereas a "striated" space is "a space drawn and riddled with lines of divide and demarcation that name, measure, appropriate and distribute space … smooth space … is defined by a flow of forces and hence is perceived haptically instead of optically. It is 'intensive' where striated space is 'extensive.'" A Body without Organs (BwO) bears a surface of smooth space that lacks zones or organs that have affective privileges over others. Striated space is one where lines and points designate itineraries and trajectories.

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[10] I do *not* intend to write a history of Islamic observatories. The remarks on observatories are to be understood as remarks on observatories as *part* of a more complex history of astronomy.

[11] For a more general view on the relationship between science and European expansion, see the contributions in P. Petitjean, C. Jami, and A. M. Moulin, eds., *Science and Empires: Historical Studies about Scientific Development and European Expansion* (Dordrecht: Springer, 1992).

[12] B. Adkins, *Deleuze and Guattari's A Thousand Plateaus: A Critical Introduction and Guide* (Edinburgh: Edinburgh University Press, 2015), 231.

[13] Adkins, *Deleuze and Guattari's A Thousand Plateaus*, 231.

[14] For the geo-philosophical aspect of this philosophy see especially G. Deleuze and F. Guattari, *Tausend Plateaus* (Berlin: Merve, 1992).

Smooth space can be perceived in and through striated space, what is seen and experienced in the world at large, in order to deterritorialise given places. In Deleuze's lexicon that pertains to space and place, deterritorialisation and reterritorialisation are the basis of most biological and philosophical activity. In this respect, the nomad is the person or thinker who constantly creates space by moving from place to place. The nomad, the philosopher and the scientist and artist alike are capable of creating spaces through the trajectories of their passages that move from one territory to another and from given striations on the surface of the world to smooth and intensive areas.[15]

This dynamic conceptualization of the movements of ideas and practices enables us to overcome the usual shortcomings of conventional histories of sciences, that is, looking at isolated aspects relating to each other superficially without being able to grasp the intersecting dynamics of the spaces mentioned here. Our style of writing follows the ongoing creation of spaces, not a linear style that is not able to map the dynamics of history. And there is dynamics even in built heritage, i. e., observatories and instruments.

## The Heritage of Architecture

We know about the vast corpus of Greek,[16] Syriac,[17] Sanskrit,[18] Pahlavi[19] and other literatures on astronomy we cannot discuss here, but these literatures may be the first indicator for the transnational – before the emergence of nations – character of astronomical (and astrological) knowledge. However, we will have to turn to observatories to move beyond the confines of mere philological manuscript studies to the integration of artifacts, instruments and institutions into a new history of Islamic astronomy. We may say, referring to Ahmad Dallal, that Arabic astronomy had integrated all available knowledge from diverse traditions (see above) already by the ninth century and was in a position to add to it. The achievements

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15 Cf. A. Parr, ed., *The Deleuze Dictionary* (Edinburgh: Edinburgh University Press, 2005), 258-259. Any shortening of these thoughts using different terminology would be gross negligence to the value of the concepts used.

16 For the reworking of Greek astronomical traditions in the Islamic world see, e. g., A. I. Sabra, "On Seeing the Stars, II. Ibn al-Haytham's 'Answers' to the 'Doubts' Raised by Ibn Ma'dān," *Zeitschrift für die Geschichte der Arabisch-Islamischen Wissenschaften* 10 (1995/96): 1-59. For an interesting example of an early introduction of regional influences see P. Kunitzsch, "Abd al-Malik ibn Ḥabīb's *Book on Stars*," *Zeitschrift für die Geschichte der Arabisch-Islamischen Wissenschaften* 9 (1994): 161-194.

17 S. Bhayro, "On the Problem of Syriac 'Influence' in the Transmission of Greek Science to the Arabs: The Cases of Astronomy, Philosophy, and Medicine," *Intellectual History of the Islamicate World* 5 (2017): 211–227.

18 For all these languages, see R. Rashed and R. Morelon, eds., *Encyclopedia of the History of Arabic Science*. vol 1: *Astronomy – Theoretical and Applied*. London: Routledge, 1996.

19 A. Panaino, "Sasanian Astronomy and Astrology in the Contribution of David Pingree," in *Kayd: Study of Mathematics, Astronomy and Astrology in Memory of David Pingree*, eds. G. Gnoli and A. Panaino (Rome: Istituto Italiano per l'Africa e l'Oriente, 2009), 73-103; and Rashed and Morelon, *Encyclopedia*.

of this period laid the foundations for developments in the following centuries.[20] To follow the fine summary of Dallal:

> The earliest planned and programmed astronomical projects were produced during the last years of the reign of al-Ma'mun (r. 813-33), at the outset of the translation movement. Under al-Ma'mun, a program of astronomical observation was organized in Baghdad (Shammasiyya) and Damascus (Mount Qasiyun). Like any organized research project, this one endowed astronomical activity in the Islamic world with formal prestige.… The professed purpose of the program was to verify and correct the Ptolemaic observations for the sun and the moon by comparing the results, derived by calculation based on Ptolemaic models, with actual observations conducted in Baghdad and Damascus some seven hundred years after Ptolemy …. The initial observations of the Shammasiyya observatory were evaluated and deemed unsatisfactory; it was only then that al-Ma'mun directed a team of astronomers to conduct additional observations at Mount Qasiyun in order to produce better results.[21]

The most famous observatory was established in the thirteenth century in Marāg1ha[22] under the patronage of the Ilkhan Hulagu and directed by Nasir al-Din al-Ṭūsī (d. 1274), one of the excellent scholars of his time (and a mathematician) who produced the famous Ṭūsī Couple when attacking Ptolemaic astronomy.[23]

Marāgha became *the* first-rate observatory, attracting scholars from throughout the regions united by the Mongol expansion. A recent history of Chinese science and technology describes the role of Marāgha in the larger Sino-Persian-Mongolian empire of knowledge. A longer quotation may be helpful to demonstrate the difficulties of identifying persons and the titles of books in a cross-linguistic research setting and introduce research not known outside the circles of specialists:

> C. M. D'Ohsson says in *A History of Mongolia* that some Chinese astronomers went with Hulagu to Persia, and that a Chinese scholar worked at the Maragha Observatory. Since then, the topic has often been mentioned by Western scholars. But up to now, his name and life have not been found. The book records merely

[20] A. Dallal, *Islam, Science, and the Challenge of History* (New Haven: Yale University Press, 2010), 35.

[21] Dallal, *Islam*, 22-23. For a general overview, see Rashed and Morelon, *Encyclopedia*.

[22] G. Saliba, "The Rôle of Maragha in the Development of Islamic Astronomy: A Scientific Revolution before Renaissance," *Revue de Synthèse* 108, no. 3-4 (July 1987): 361-373.

[23] G. Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), 188. For one of his major astronomical works, see F. J. Ragep, *Nasir al-Din al-Tusi's Memoir on Astronomy (al-Tadhkira fi 'Ilm al-Hay'a), with Translation and Commentary* (New York: Springer, 1993).

> "Fao-moun-dji" the phonetic translation of his name. Since the life of the Chinese astronomer is unknown, we can only guess the three Chinese characters of his name from the sound. For example, Joseph Needham adopts these three characters "傅孟吉" as his name in Chinese.
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> The saying of C. M. D' Ohsson came from a Farsi annals entitled *The Garden of Doyens*. That book was completed in 1317, divided into 9 volumes, and Volume 8 is *A History of Chine*, which records such a story as in the following paragraph:
>
> In the Hulagu period, Chinese scholars and astronomers came with him to this place (Iran). Among them, there was a teacher named Tu Michi, from whom the scholar Nasr al-Din Talost[24] learned the Chinese technique of astronomical deduction in compiling the *Ilkhanate Astronomical Table* under the order of Hulagu. Furthermore, when the Islamic monarch Ghazan Mahmud Khan ordered to write *A History of the Praised Ghazan*, Prime Minister Rashid al-Din called in Chinese scholars Li Dachi and Ni Kesun for assistance. Both were proficient in medicine, astronomy and history, and brought with them various books on these subjects. In addition, they lectured on chronological record of China, and they said the number of years and the stem-branch were undetermined.
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> Anyhow, the compilation of the Ilkhanate Astronomical Table is the most significant merit that Nasr al-Din Talost accomplished at the Maragha Observatory. Therefore, we get to know that Chinese astronomers made important contributions to the Ilkhanate Astronomical Table."[25]

We notice the first link between Persian astronomy and Chinese astronomy taking place in the observatory of Maragha. This turned into an important agent of scientific history including the observatory, the instruments, and the huge library as well as contacts with China.

Starting with the Maragha Observatory, the 14th to the 15th century became an era of unprecedented progress in astronomical and mathematical knowledge – extending in some cases to the 18th century. One of the central regions that was part of this progress was the Uzbek realm in the time of Ulugh Beg.[26] In our context, the Ulugh Beg Observatory (finished in 1429) is a pertinent case demonstrating the historical embeddedness of this architectural landmark, in itself worth being studied, in a global history of sciences.[27]

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24 A misrepresentation of the name of al-Ṭūsī.

25 Yongxiang Lu, ed., *A History of Chinese Science and Technology*, vol. 1 (Heidelberg: Springer/Shanghai: Jiao Tong University Press, 2015), 107-108.

26 For his rule, see V. V. Barthold, *Four Studies on the History of Central Asia*. vol. 2, *Ulugh Beg* (Leiden: Brill, 1958). For him as an astronomer, see B. van Dalen, "Islamic and Chinese Astronomy under the Mongols: a Little-Known Case of Transmission," in *From China to Paris: 2000 Years Transmisson of Mathematicla Ideas*, ed. Y. Dold-Samplonius et al. (Stuttgart: Franz Steiner, 2002), 327-356.

27 The ruler himself was mentioned in a dedication of a manuscript on astronomy by al-Jaghmīnī (*al-Mulakkhaṣ fī al-hay'a*, Rare Book and Manuscript Library, Columbia University, MS Or 21).

Architecture can be seen as an indicator of societal structures as can be illustrated by the buildings in Registan Square in Samarqand, spatially not related to the Samarqand Observatory but intrinsically related to mathematical-astronomical studies in Samarqand. The Ulugh Beg *madrasa*, a center for mathematical studies and other (religious) disciplines, and the *khānaqāh*, a center for Sufis, faced each other, opposing and cooperating at different times.[28]

The observatory of Samarqand inspired other architectural activity in South Asia, in particular the Jantar Mantar in the modern City of New Delhi. It was built from 1723 to 1724 under the ruler Jai Singh II of Jaipur and consists of thirteen architectural astronomical instruments. From 1727 to 1734, other observatories were built under the rule of Jai Singh II, all known under the name Jantar Mantar. Jai Singh was passionately interested in mathematics and astronomy. He adapted the design of earlier observatories, integrating elements of the Samarqand tradition and following the approach of the Islamic tradition of astronomy.[29]

We find here a link to the Samarqand tradition of architecture, the study of astronomy and mathematics at the core of one of the finest examples of built astronomy,[30] interestingly supported by a non-Muslim ruler (Rajput) under a Muslim emperor.[31] This may be called the smooth space of Samarqand- and Maragha-inspired architecture, striated again in local forms.

## Byzantium as Part of Southwest Asia

Other zones of contact have to take account of the Byzantine-Islamic and the Byzantine-Western European zone of contact. Since the research on these zones of contact is often ignored by mainstream research on the history of astronomy, it can best be introduced in our discussion by a quotation from recent research:

> The movement of continuously reforming Greek astronomy became so important that it apparently attracted the attention of astronomers from outside the Islamic

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28 A. Mekking and E. Roose, eds., *The Global Built Environment as a Representation of Realities: Why and How Architecture Should Be Subject of Worldwide Comparison* (Utrecht: Pallas Publications, 2009), 98-111.

29 B. Perlus, "Architecture in the Service of Science: The Astronomical Observatories of Jai Singh II," Jantarmantar.org, accessed November 10, 2018, http://www.jantarmantar.org/Architecture_Science_web.pdf. The links between South Asia and East Asia cannot be analyzed here. We may just assume that there have been links between Central Asia, South Asia (in this case inspired by Central Asian astronomy) and East Asia due to relations in other fields. Further research to establish these links has to be done.

30 Not buildings for astronomical research, but astronomy taking the shape of buildings, if we follow recent research on the agency of laboratories, instruments and other artifacts in the history of sciences inspired by Latour and mentioned before.

31 For recent research on Maragha linking it to Samarqand and Jantar Matar, see J. S. Niri, "An Inquiry into Maragheh Observatory: The First International Scientific-Research Foundation of the Ilkhanid Era," *International Journal of Humanities* 25 (2018): 77-93.

> domain. We know, for example, that Byzantine astronomers, like Gregory Chioniades (fourteenth century) and others, would travel to the Islamic lands in order to learn of the latest developments in Islamic astronomy and to report their findings back to their compatriots in their own Greek language. In fact, one can also document the dependence of the late Byzantine astronomy on Islamic astronomy by simply browsing through the technical terminology that was used by Byzantine astronomers at the time. This terminology demonstrates very clearly that it bore a much closer resemblance to the Arabic sources, from which it was derived, than to the classical Greek texts such as those of Ptolemy.
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> With the fall of Constantinople in 1453 to the Ottoman Turks, and the ultimate demise of the Byzantine empire, a good number of Byzantine scholars escaped westward, at times together with their books. But by then the Byzantine civilization had been in direct contact with the Islamic civilization for centuries already. And as a result those books inevitably bore the marks of having been influenced by the intellectual production of the Islamic civilization, and thus contained some of the developments that had already taken place in that civilization.[32]

Leaving aside the problematic idea of *one* civilization, we now can tell another story of entangled histories between Byzantium, the eastern Islamic world, and Western Europe. Another smooth space emerges, the space of translation of Arabic and Persian texts and discussions into Greek, a common linguistic space producing a striated space of specific Greek manuscripts. These manuscripts were brought to Europe creating another smooth space, that of a European space of astronomical research that later on influenced astronomical research from European to Chinese spaces and thus turned striated again. This held true even after the demise of the Byzantine Empire when the Ottomans stepped into these networks.[33]

We may add to our stories the observatory of Taqī al-dīn (d. 1585), an Egyptian in Ottoman Istanbul,[34] which also followed the lines of the Central Asian tradition. In addition, due to his competition with Tycho Brahe (d. 1601), a European astronomer, we can see another contact of ideas, with Brahe following the same architectural lines in his observatory of Uraniborg on the island of Hven in modern Denmark.[35]

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32 G. Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, MA: MIT Press, 2007), 194-195.

33 For the sake of creating another striated space, we may note that Copernicus' writings were translated into Ottoman Turkish at a very early stage and wholeheartedly embraced.

34 See his biography in C. Şenel, "Nevizade Ataî'nin Hadaikü'l-Hakaik'inden Takiyyüddin'in Biyografisi," *Osmanlı Bilimi Araştırmaları* 10 (2009): 130-133.

35 V. E. Thoren, *The Lord of Uraniborg: A Biography of Tycho Brahe* (Cambridge: Cambridge University Press, 1990).

## Chinese-Persian Spaces

Turning eastward, we may add to our overview Guo Shoujing (d. 1316), engineer, astronomer, and mathematician.[36] For our discussion, it is noteworthy that Guo, who built the Gaocheng observatory, was influenced by the Persian astronomer and geographer Jamāl al-Dīn Muḥammad b. Ṭāhir al-Bukhārī (d. around 1301), who was sent from the Maragha Observatory[37] in 1267 to confer with Chinese astronomers[38] and was the first director of the Islamic Astronomical Bureau founded under Khubilai Khan in 1271. Jamāl al-Dīn was associated with an astronomical handbook, a *zīj*, translated into Chinese. He was part of a growing group of Persians living in the Chinese part of the Mongol Empire,[39] another link to our previous remarks on Marāgha Observatory: "undoubtedly it occupies a vital position in the history of Islamic astronomy – it can be considered as a midway station between the Observatory and the Samarkand Observatory of the subsequent Timurid Dynasty."[40]

However, are there other forms of evidence that may support our thesis about the dynamic interaction of different elements of history along the Silk Roads? The Islamic Astronomical Bureau may give us some hints on further sources of the entangled histories of astronomy. At least a booklist of the library of the Bureau of Astronomy gives an idea of written sources available at the library possibly written in Arabic or Persian.[41] Although there are manuscript records hinting at the existence of manuscripts of Islamic astronomical tables even in the Korean archive, we may not overstate the influence of the movement of knowledge.[42]

This may be the first indicator of the importance of libraries as another group of agents in the history of sciences, in our case, astronomy. We have mentioned the difficulties of identifying the astronomers; some of the names in the list of books of the Islamic Astronomical Bureau remind us of Persian or Arabic names. Therefore, we add to our

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[36] I. Ma, "Islamic Science of Astronomy and Calendrical Technology in the Medieval China and Significant Contribution to the Chinese Science of Astronomy and Calendrical Technology in the Chinese Northern Sung Dynasty," Academia, accessed November 11, 2018, https://www.academia.edu/5918944/Islamic_Science_of_Astronomy_and_Calendrical_Technology_in_the_Medieval_China_and_Significant_Contributions_to_the_Chinese_science_of_astronomy_and_Calendrical_Technology_in_the_Chinese_Northern_Sung_Dynasty gives some insights into the Arab-Chinese connections in the field of astronomy.

[37] The built space of astronomy as a zone of contact.

[38] J. Needham, "The Peking Observatory in A.D. 1280 and the Development of the Equatorial Mounting," *Vistas in Astronomy* 1 (1955): 67-83.

[39] For an overview, see B. van Dalen, "Islamic and Chinese Astronomy," 327-356.

[40] Lu, *A History of Chinese Science and Technology*, 108.

[41] Lu, *A History of Chinese Science and Technology*, 108-109.

[42] K. Yabuuti, "The Influence of Islamic Astronomy in China," in "From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy," eds. D. King and G. Saliba, special issue, *Annals of the New York Academy of Sciences* 500, no. 1 (1987): 547-559.

overview of agents of the history of astronomy[43] the astronomers and the information we may glean from their biographies.

## Biographical Evidence

By definition, a combination of striated spaces embedded in larger smooth spaces of transnational astronomical research is to be found in biographies. Reading the biographies of astronomers like Jamāl al-Dīn tells us how the connecting lines of global astronomic research worked. The leading scientists at the observatory and the Ulug Beg madrasa were al-Kāshī, Qāḍīzāde and Qūshjī.[44]

The results of the observations made under Ulug Beg include precise measurements of the obliquity of the ecliptic with results close to the actual value and that of the latitude of Samarqand (close to the actual value, too). It was a turning point for the history of sciences in Central Asia that Ulug Beg was killed in 1449 CE. The other astronomers mentioned faced different fates. Jamshīd al-Kāshī (d. 1429 CE), astronomer and mathematician, taught at the Ulug Beg madrasa, and as a teacher and prolific writer contributed to many fields of the sciences.[45] Qāḍīzāde was a famous commentator of Mahmud al-Jaghmini's astronomical compendium entitled *al-Mulakhkhaṣ fī ʿilm al-hayʾa al-basīṭa* (1412)[46] and another important work on geometry. Both commentaries were popular for a long time as indicated by a large number of manuscripts. Thus, we find supercommentaries on these works by Ottoman scholars like Sinān Pāshā (d. 1486). These individuals continued the tradition of Samarqand, disseminating this tradition throughout Ottoman[47] and Persianate lands. Intermarriages between the families of Qāḍīzāde and Qūshjī prove the biological continuation of this tradition in the Ottoman Empire.[48]

ʿAlī Qūshjī was born in Samarqand and after the death of Ulug Beg travelled via Herat, Tashkent, and finally Tabriz before he settled in the Ottoman Empire before 1472 CE. There

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43 Following the approach of Latour (see above) for the history of sciences, we are not privileging humans as the only actors in the history of sciences.

44 B. van Dalen. "Ulugh Begh: Muḥammad ibn Ṭaraghāy ibn Shāhrukh ibn Tīmūr," in *The Biographical Encyclopedia of Astronomers,* eds. T. Hockey et al (New York: Springer, 2007), 81-96.

45 Just one example of his writings is discussed in E. S. Kennedy, "Treatise V of Kāshī's Khāqānī Zīj: Determination of the Ascendence," *Zeitschrift für die Geschichte der Arabisch-Islamischen Wissenschaften* 10 (1995/96): 123-145.

46 For more details, see S. P. Ragep, *Jaghmīnī's Mulakhkhaṣ: An Islamic Introduction to Ptolemaic Astronomy* (Dordrecht: Springer, 2016). The dedication of a manuscript of this work to Ulug Beg was mentioned before.

47 There is a link to the knowledge generated in Maragha, too [see S. Aydüz, "Nāṣir al-Dīn al-Ṭūsīs Influence on Ottoman Scientific Literature (Mathematics, Astronomy and Natural Sciences)," *International Journal of Turkish Studies* 17 (2011): 21-38].

48 See F. J. Ragep, "Copernicus and his Islamic Predecessors: Some Historical Remarks," *History of Science* 45 (2007): 65-81; and F. J. Ragep, "ʿAli Qushji and Regiomantanus: Eccentric Transformations and Copernican Revolutions," *Journal for the History of Astronomy* 36, no. 4 (2005): 359-371.

he wrote many books on astronomy, mathematics, *kalām*, *fiqh*, mechanics, and language. He made an important step from Aristotelian physics towards an independent astronomical physics. Remarkable is the coincidence between his findings and Copernicus' *De revolutionibus* on earth's motion. Qūshjī demonstrates another link between Samarqand or the Uzbek region and in this case the Ottoman Empire reaching out to Europe. Thus, he is part of the creation of a smooth space of astronomical research in Europe, southwest Asia, and Central Asia reaching out to East Asia. We have already mentioned the books at the Islamic Astronomical Bureau in China and the *zīj* produced in Maragha. Thus, we have to turn to manuscripts as agents in the history of science.

## Manuscript Evidence

These links to Europe can be better understood by looking into the manuscript evidence, a very specific striated space producing a larger smooth space of astronomy – and being created as part of this smooth space. As is well known, the astronomical tables and the handbook known as *Zīj-e Ulugh Beg, Zīj-e Gurgānī* or *Zīj-e jadīd-e sulṭānī* are among the best astronomical handbooks of the Ptolemaic tradition and were translated into French in the middle of the 19th century,[49] establishing another link leading into Western Europe.[50] However, there are additional manuscript links between Byzantium and Western Europe that we have to take into account:

> Arabic and Persian scientific texts were apparently already digested in the Byzantine Greek sources for a period of at least about two centuries or so, before those Byzantine texts were brought into Europe. This time, their contents were not apparently translated into Latin. Rather, because of the emphasis of the Renaissance intellectual environment on the Greek language, they were read in the original Greek. The best of their contents, which were originally Arabic and Persian could now be directly assimilated into the Latin texts, without having to translate the whole text into Latin.[51]

Thus, we may be justified in saying we have a Greek language space intersecting the Arab-Persian linguistic space, both, linguistically speaking, striated spaces turning, astronomically speaking, into a smooth space of global research.

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49 Van Dalen, "Ulugh Begh."

50 For a survey of this literature see E. S. Kennedy, "A Survey of Islamic Astronomical Tables," *Transactions of the American Philosophical Society* 46, no. 2 (1956): 121-177; and D. A. King and J. Samsó, "Astronomical Handbooks and Tables from the Islamic World (750-1900): an Interim Report," *Suhayl* 2 (2001): 9-105.

51 Saliba, *Islamic Science*, 195.

Manuscript evidence indicates another connectivity leading into Europe produced by individuals such as Guillaume Postel,[52] a polymath, professor of Semitic languages, translator for French diplomatic missions in the Ottoman Empire, and buyer of oriental language manuscripts on sciences. The manuscripts bought by him document the intense interest in astronomic sciences in Europe. He is famous for his work being a crossroads of the history of many ideas bringing into contact Asian and European developments.[53]

The importance of this manuscript link can be demonstrated by the surprising fact that analytical diagrams found in Arabic manuscripts can be found in the writings of the European astronomer Copernicus (d. 1543). Evidently, he was peeking over the linguistic barrier of the Persian-Arabic scientific community, picking up whatever he needed for his technical work. Not knowing Arabic, he managed to acquire mathematical diagrams from the original Arabic works and developed his own Latin terminology. This may explain mistakes and the sometimes slavish[54] mimicking of the original. However, this tells us that there were oriental-occidental linkages such as those I have mentioned before. Other links between European Renaissance astronomy and Arabic scholarship can be found in the specialized field of cometary theory.[55]

From a global history perspective, the histories of the observatories and the related agents of the history of astronomy I have been talking about teach us a most important lesson. For global history, these relations between the flourishing of sciences and the living culture of sciences in the Islamic realm and especially in Central Asia are an opportunity to a) deconstruct the longstanding Eurocentric view of a decline of sciences in these areas and the inevitable ascendance of the European West, and b) to reconstruct the networks of exchange of science and scholars inspiring new thoughts, in our case on astronomy reaching from China to Europe. Observatories and their histories – agents of the history of sciences as we have seen – provide us with excellent examples for a better understanding of the many ways knowledge has traveled. As Ben-Zaken says focusing on the Eastern Mediterranean, we may understand this region as another zone of contact and intersection where the practitioners of astronomy searched for long-lost past knowledge serving as tools for the new cosmologies.[56]

Methodologically speaking, I have been talking about entangled histories from China via

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52 For Postel, see M. L. Kuntz, *Guillaume Postel – Prophet of the Restitution of All Things: His Life and Thought* (The Hague: Martinus Nijhoff, 1981).

53 Kuntz, *Guillaume Postel*, XI.

54 Cf. G. Saliba, "The Rôle of Maragha, 361-373.

55 See G. Saliba, "Cometary Theory and Prognostications in the Islamic World and their Relationship to Renaissance Europe," in *The Occult Sciences in Pre-modern Islamic Cultures*, eds. N. El-Bizri and E. Orthmann (Würzburg: Ergon Verlag i. Komm, 2018), 105-134. See especially the remarks on sloppy modern scholarship in Kuntz, *Guillaume Postel*, 126.

56 A. Ben-Zaken, *Cross-Cultural Scientific Exchanges in the Eastern Mediterranean, 1560–1660* (Baltimore, MA: The Johns Hopkins University Press, 2010), 163. We leave the role of the pirates the author mentions out of the picture for this moment.

the Silk Roads, maritime and terrestrial, passing through Samarqand, and the elements that are part of these histories. In addition, I have been talking about hybrid history leading to Europe via Byzantium and later the Ottoman Empire.[57]

I have to mention the link via Jewish scholars in al-Andalus to Renaissance Italy, well known by now as another aspect of the histories we are talking about.[58] Talking about the smooth space of astronomical research leads us – in an Islamic context – to the intersection of astronomy and another smooth space, Islamic theology. This intersection produces another striated space, i. e., Islamic astronomy. The history of Islamic astronomy needs a thorough understanding of the ideational framework it develops in, i. e., the transformations of the interconnected field of Islamic theology, philosophy and mysticism, creating a new open worldview now called post-classical Islamic philosophy.[59]

## Astronomy and Theology

Theology, Islamic theology (*kalām*) not only philosophy, is to be contextualized in the histories we have discussed in this study. However, is the development of theology – especially in Central Asia and the Persianate world in general[60] – imaginable without the observations in observatories and the theoretical knowledge produced there, derived from these observations? We may assume developments in the fields of astronomy, mathematics, etc., enabled theological thinkers (some well versed in astronomy) to open up to new ideas in the sciences of the day. To understand this specific way of integrating astronomic and scientific knowledge and theology will be helpful to analyze the process of integrating this knowledge in other cultural contexts. Thus, we will follow global history and its transformation and localization and regionalization. Just a few case studies of three famous scholars[61] of the Central Asian realm may shed light on this aspect of the post-classical history of Islamic theology. The case studies cover the cases of ʿAḍud al-Dīn al-ʿĪjī, Ṣadr al-Sharīʿa al-Bukhārī, and Niẓām al-Dīn al-Naisābūrī.[62]

One of the most influential works in post-classical Sunni theology is by ʿAḍud al-Dīn

[57] In particular, the links between the Ottoman Empire and Europe are promising fields of further research.

[58] J. Ibn Naḥmias, *The Light of the World: Astronomy in al-Andalus*, ed. and trans. R. G. Morrison (Berkeley, CA: University of California Press, 2016).

[59] For this transformation of theological, philosophical and mystical thought, see F. Griffel, *Den Islam denken: Versuch, eine Religion zu verstehen* (Kitzingen: Reclam, 2018) for the case of Central Asia.

[60] We are not talking about the history of Islamic theology in general.

[61] Being aware that we are still in need of a history of post-classical Islamic theology, philosophy and Sufism, any attempt to go beyond the level of case studies would be premature.

[62] Cf. R. Lohlker, "Reflections on Science and Religion in Islam," in *Voices of Three Generations: Essays in Honor of Seyyed Hossein Nasr*, eds. M. A. Faghfoory and K. O'Brien (Chicago, IL: Kazi Publications, 2019), 217-223.

al-ʿĪjī (d. 1355) entitled *Stations of Knowledge on Speculative Theology*.[63] In this work, al-ʿĪjī wrote extensively on astronomy; however, he wrote no independent work on these themes, for his real interest was theology.[64] Astronomy was discussed only in relation to theology. This is not surprising when we bear in mind that specialists such as al-ʿUrḍī wrote that astronomy, because it was closest to theology, was such an outstanding branch of the mathematical disciplines.[65]

Al-ʿĪjī's real aim was to refute philosophy's claim to absoluteness. Only thus can it be explained why al-ʿĪjī repeatedly points out that there are possible alternative explanations for natural phenomena which differ from those of the philosophers. This approach is found also in al-ʿĪjī's rendering of different theories of astronomy, in which he frequently refers to alternative explanations, without, indeed, developing an alternative model.[66] However, he does not argue in favor of any of the possibilities. In summary, his assessment is that none of the treated theories are the subject-matter of theology. Al-ʿĪjī does not place theology as a hegemonic form of knowledge; rather, he creates a free space in which the autonomy of the individual disciplines is maintained. Obviously, the final agency rests with God.

This autonomy is formulated with more clarity by one of his contemporaries. Ṣadr al-Sharīʿa al-Bukhārī (d. 1346/47),[67] known as the Younger or the Second, was better known for his juridical writings, but here the focus is on another work, the three-volume *Structure of the Sciences*.[68] The first volume of this, on logic, relays the then-prevailing view in this discipline: since the perfection of the soul is attained by the acquisition of theoretical knowledge, it runs the risk of falling into error, and it requires a criterion against which this knowledge can be judged. This, precisely, is logic. However, since logic occupies itself with formal aspects, it cannot pronounce itself on worldly fundamental assumptions.

The volume that follows is devoted to theology. The object of theology is the Essence of God, including His Existence and Oneness, His Attributes and the conditionality of the existence/being of created matter. The discourse on essence and existence, on substance and

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[63] I follow here with modifications the ideas in A. S. Dallal, *Islam, Science, and the Challenge of History* (New Haven: Yale University Press, 2010), 131-134. Particularly enlightening is R. G. Morrison, "What was the Purpose of Astronomy in al-Ījīs *Kitāb al-Mawāqif fī ʿilm al-kalām*," in *Politics, Patronage and the Transmission of Knowledge in 13th-15th Century Tabriz*, ed. J. Pfeiffer (Leiden: Brill, 2013).

[64] ʿAḍud al-Dīn al-Ījī, *Kitāb al-Mawāqif* (with the commentary of al-Jurjānī), ed. Muhammad Badr al-Din al-Naʿsan (Cairo, 1907). For this work and others by the author, see J. van Ess, *Die Erkenntnislehre des ʿAḍud al-Dīn al-Ījī* (Wiesbaden: Harrassowitz, 1966).

[65] S. Tekeli, "Al-ʿUrdī,s Article on 'the Quality of Observation,'" Foundation for Science Technology and Civilisation, accessed October 8, 2018, http://www.muslimheritage.com/uploads/Al_Urdi_Article.pdf, 4. For the biography of al-ʿUrdi (d. 1266), see P. G. Schmidl, "ʿUrḍī: Muʾayyad (al-Milla wa-) al-Dīn (Muʾayyad ibn Barīk [Burayk]) al-ʿUrḍī (al-ʿĀmirī al-Dimashqī)," in *The Biographical Encyclopedia of Astronomers*, eds. T. Hockey et al. (New York: Springer, 2007), 1161-1162.

[66] Morrison, "What was the Purpose of Astronomy," 204.

[67] We have to think of another Bukharan, an astronomer travelling to China (see above).

[68] I follow here with modifications the consideration in Dallal, *Islam*, 135.

accident, and on matters of astronomy is germane only in respect of God, as in al-ʻĪjī.[69] In the ensuing discussion of Existence, Being, and other matters, Ṣadr al-Sharīʿa argues that such matters have significance only when these are structured in relationship to that which has an external material existence. The aim of this and other discussions is to provide evidence that the assumption of a conceptual existence is to be rejected, and that all these entities have to be connected to an external material existence that in turn must spring from God. Ṣadr al-Sharīʿa skillfully debated using rational argumentation, but introduced also *ḥikmah*, practical wisdom, to distance himself from philosophy. He stated, however, that rational argument is not able to provide proof of the truth of God. Here, too, there is a conflict in the Islamic intellectual discussion between theologians and philosophers, wherein the former aim to undermine the comprehensive claim of the latter.

Motivated by this rejection of a comprehensive claim, Ṣadr al-Sharīʿa argues in a more detailed manner than does al-ʻĪjī for a constraint on the scope of the claims of theology and likewise creates through this an opening for other forms of knowledge. One of these forms of knowledge is astronomy, which he deals with in the third volume.[70] He leaves out completely the metaphysical implications of astronomy. His objective is a mathematically-grounded understanding of celestial phenomena, the knowledge of which was further improved through the observatory established in 1259 AD by the Maragha School (see above), of whose tradition Ṣadr al-Sharīʿa was a follower. His theological reflections enabled him to follow the purely scientific tradition of an astronomy-oriented approach, and leave out the metaphysical aspect of earlier astronomy. This also led to the relinquishing of diverse principles of Aristotelian natural philosophy. All this led him towards the acceptance of the existence of universes other than those known to us. It even allowed for insights based on astronomy to influence his theological argumentation.

Ultimately, there is a correlation between the discipline of theology (*kalām*) and other religious disciplines and natural science that progresses according to its own rules. Both dimensions of knowledge, however, move within a frame of reference circumscribed by Quranic revelation.[71]

Let us turn to a third example. Niẓām al-Dīn al-Naisābūrī (d. 1330 AD) is one of the most notable figures in the Central Asian-Iranian history of ideas, and one who was also well-known in South Asia. Known for his commentary on the Quran, he also produced many works in the areas of theology, the Arabic language, philosophy, mathematics, geometry

[69] See, for example, Ṣadr al-Sharīʿa, *al-Qism al-thānī min taʿdīl al-ʿulūm maʿa sharḥihī*, Maktabat al-Malik ʿAbdallāh b. ʿAbdalʿazīz Ms. 445 (extant only as manuscript).

[70] See also A. S. Dallal, *An Islamic Response to Greek Astronomy by Kitāb Taʿdīl hayʾat al-aflāk of Ṣadr al-Sharīʿa* (Leiden: Brill, 1995).

[71] A similar process of freeing sciences can be witnessed in the case of philosophy. F. J. Ragep, "Freeing Astronomy form Philosophy: An Aspect of Islamic Influence on Science," *Osiris* 16 (2001): 49-71 (pp. 66-71 contain a translation of a text from al-Qūshjī).

(theoretical, not applied), and, in particular, astronomy. He thus built the oft-required bridge between the Islamic disciplines and the so-called "foreign" sciences. His commentaries on the Quran contain natural scientific-philosophical information and discussions. Central to his study of natural science disciplines was an interest in a better understanding of Creation. This took place on the basis of already well-developed natural science disciplines such as astronomy. In this respect, the configuration of the various disciplines in his time differed from those of earlier centuries. His example clearly shows that it was possible to unify religious and scientific disciplines; the two were, for him, not separate. Natural scientific insight was part of his religious scholarship and vice versa. I cannot go into detail here, but a comparison between al-Naisābūrī's natural-philosophical/scientific works and his religious works displays striking analogies in the line of argumentation used.[72]

In particular, he was against a rejection of the value of understanding natural science for Quranic exegesis, which *inter alia* was represented by leading Sunni commentators on the Quran such as Fakhr al-Dīn al-Rāzī (d. 1209). Unlike the authors referred to before, al-Naisābūrī sought to support his argument not through speculative theology, but by reference to the Quran and Islamic law. On the one hand, a motivation can be detected of the study of nature through religious considerations; on the other, we can extrapolate from his natural philosophical/scientific work that his discipline-specific considerations frequently disengaged themselves from a narrow religious viewpoint, which, nevertheless, continued to be the framework. We may say this part of the history of astronomy is at the same time part of the contradictory histories of what is Islam.[73]

This can be stressed if we add some insights from another field of research related to our present one, philosophy. Vagelpohl[74] writes in his study of the translations of Aristoteles' *Rhetoric*:

> The second aspect of what I have termed the "philological outlook" is its tendency to project a particular division of the "intellectual universe" on the medieval Islamic societies that initiated and nurtured the translation movement. Perhaps inevitably, the concept of a divide between science, philosophy and religion that is often taken as a point of departure for the study of the Greek-Arabic translations is our own, that of the contemporary observer. The writings of the eighth-century Islamic philosopher and polymath Abū Yūsuf Yaʿqūb ibn Isḥāq al-Kindī (d. ca.

[72] R. G. Morrison, *Islam and Science: The Intellectual Career of Nizam al-Din al-Nisaburi* (London: Routledge, 2007), 146.

[73] For this concept, see Sh. Ahmed, *What is Islam? The Importance of Being Islamic* (Princeton, NJ: Princeton University Press, 2015).

[74] Vagelpohl writes in his study about crucial distinctions in the history of sciences to be discareded to reach a new epistemology to allow for an adequate study of new or re-reading of known sources. This quotation corroborates the findings in this study. Shortening it would leave the reader without knowledge of a very specialized discussion and opportunity to compare the findings.

> 870) illustrate very well why such modern distinctions between different intellectual spheres stand in the way of a full appreciation of medieval Islamic scholars and their thought: on the basis of an al-Kindī commentary on a mathematical treatise about *The Measurement of the Circle* by the great mathematician and engineer Archimedes (d. ca. 212 BCE), Roshdi Rashed demonstrates al-Kindī's reliance on mathematical proofs as both a "paradigm to be respected and an ideal to be attained." For al-Kindī, the study of mathematics was a necessary prerequisite for the study of philosophy and science. Philosophical argumentation provided him the means to reach an understanding of and defend religious doctrines. Unlike later philosophers, who stressed the role of logic as the paramount instrument for gaining knowledge, al-Kindī held that mathematical proofs supplied the uniting methodological framework for all intellectual activity, be it "science," "philosophy" or "theology." The example of al-Kindī casts considerable doubt on the validity of familiar distinctions between "science," "philosophy" and "religion" in the context of the early translation movement.
>
> Likewise, the relation between science as understood by al-Kindī on the one hand, i. e. the totality of human intellectual effort, and translation on the other has often (but not always) been regarded as one of precedence in time and content: translations spawned "science." Again, Roshdi Rashed persuasively argues for a less schematic approach. On the basis of examples from mathematics and optics, he demonstrates that the need for specific translations was often caused by previous research. Concrete research agendas led to the identification and translation of Greek texts deemed useful to solve specific scientific problems. Thus, the relationship between research and translation can be better understood as dialectical with research promoting translation and translations changing or giving rise to entirely new research agendas.[75]

Although we are not talking about translations and sciences, we may postulate a similar dialectical relationship of Islamic theology and sciences casting "considerable doubt" on the distinctions between sciences and theology: sciences spawning the need for new theological instruments of thought opening up space to build observatories and not opposing building observatories.[76] Thus, we may refine conceptualizations like Shahab Ahmed's (see above) including sciences as an integral part of Islam creating new assemblages with intersecting smooth and striated spaces.

Returning to the global history level, we may assume that there are other assemblages

[75] U. Vagelpohl, *Aristotle's "Rhetoric" in the East: The Syriac and Arabic Translation and Commentary Tradition* (Leiden: Brill, 2008), 2-3.

[76] We may add that religious opposition to observatories arose in, e. g., Istanbul and Samarqand. The reasons were, however, religiously legitimated conflicts of power.

and their spaces. Exploring these spaces will enable us to understand the movements leading to an integration of sciences in the striated spaces of different cultural contexts, e. g., creating an Islamic astronomy in China and involving Chinese scholars in astronomical and other research in the Caucasus, with all its further repercussions for other parts of the world. This will enable us to understand possible variants of the integration of astronomy in different contexts. The Islamic aspect may become less important, other aspects becoming more important. These changes, intersections and merging take place in an institutional context, based in buildings, using instruments in these buildings, referring to scientific traditions transmitted in manuscripts, and all this done by researchers/scholars bringing in all their ideas, even other than scientific ones, e. g., theological (but many others, too).

Reading the history of sciences in this way as a global, interconnected enterprise going far beyond the framework of a history of ideas of a specific linguistic[77] and geographic region will give rise to "entirely new research agendas"[78] integrated with the Silk Roads as the overarching metaphor.

[77] A very interesting case of linguistic variety in the history of astronomy is the work of Qutb al-Din al-Shirazi (d. 1311) (K. Niazi, *Qutb al-Din Shirazi and the Configuration of the Heavens: A Comparison of Texts and Models* (Dordrecht: Springer, 2014). Although he was able to write in Arabic, there are other works authored by him in Persian. Thus, deepening research into the linguistic aspects of the history of Islamic astronomy is needed.

[78] Vagelpohl, *Aristotle's "Rhetoric" in the East*, 3.

## References

Adkins, Brent. *Deleuze and Guattari's A Thousand Plateaus: A Critical Introduction and Guide*. Edinburgh: Edinburgh University Press, 2015.

Ahmed, Shahab. *What is Islam? The Importance of Being Islamic*. Princeton, NJ: Princeton University Press, 2015.

Al-Ījī, Aḍud al-Dīn. *Kitāb al-Mawāqif* (with the commentary of al-Jurjānī). Edited by Muhammad Badr al-Din al-Na'san. Cairo, 1907.

Aydüz, Salim. "Nāṣir al-Dīn al-Tūsī's Influence on Ottoman Scientific Literature (Mathematics, Astronomy and Natural Sciences)." *International Journal of Turkish Studies* 17, no. 1-2 (2011): 21-38.

Barthold, Vasili Vladimirovitch. *Four Studies on the History of Central Asia,* vol. 2, *Ulugh Beg*. Leiden: Brill, 1958.

Bauer, Thomas. *Die Kultur der Ambiguität*. Berlin: Verlag der Weltreligionen, 2011.

Ben-Zaken, Avner. *Cross-Cultural Scientific Exchanges in the Eastern Mediterranean, 1560–1660*. Baltimore, MA: The Johns Hopkins University Press, 2010.

Bhayro, Siam. "On the Problem of Syriac 'Influence' in the Transmission of Greek Science to the Arabs: The Cases of Astronomy, Philosophy, and Medicine." *Intellectual History of the Islamicate World* 5, no. 3 (2017): 211-227.

Dallal, Ahmad S. *Islam, Science, and the Challenge of History*. New Haven: Yale University Press, 2010.

_____. *An Islamic Response to Greek Astronomy by Kitāb Taʿdīl hay ʾat al-aflāk of Ṣadr al-Sharīʿa*. Leiden: Brill, 1995.

Deleuze, Gilles, and Félix Guattari. *Tausend Plateaus*. Berlin: Merve, 1992.

Forêt, Philippe, and Andreas Kaplony, eds. *The Journey of Maps and Images on the Silk Road*. Leiden: Brill, 2008.

Fragner, Bert G. *Die "Persophonie": Regionalität, Identität und Sprachkontakt in der Geschichte Asiens*. Berlin: Das Arabische Buch, 1999.

Gerstenberger, Debora, and Joel Glasman. *Techniken der Globalisierung: Globalgeschichte Meets Akteur-Netzwerk-Theorie*. Bielefeld: Transcript Verlag, 2016.

Green, Nile. *The Persianate World: The Frontiers of a Eurasian Lingua Franca*. Oakland, CA: University of California Press, 2019.

Griffel, Frank. *Den Islam denken: Versuch, eine Religion zu verstehen*. Kitzingen: Reclam, 2018.

Ibn Naḥmias, Joseph. *The Light of the World: Astronomy in al-Andalus*. Translated and edited by R. G. Morrison. Berkeley, CA: University of California Press, 2016.

Jeong, Su-Il. *The Silk Road Encyclopedia*. Irvine, CA: Seoul Selection, 2016.

Kennedy, Edward Stewart. "Treatise V of Kāshī's Khāqānī Zīj: Determination of the Ascendant." *Zeitschrift für die Geschichte der Arabisch-Islamischen Wissenschaften* 10 (1995/96):

123-145.

_____. "A Survey of Islamic Astronomical Tables." *Transactions of the American Philosophical Society* 46, no. 2 (1956): 121-177.

King, David A., and Julio Samsó. "Astronomical Handbooks and Tables from the Islamic World (750-1900): an Interim Report." *Suhayl* 2 (2001): 9-105.

Kunitzsch, Paul. "ʿAbd al-Malik ibn Ḥabīb's *Book on Stars*." *Zeitschrift für die Geschichte der Arabisch-Islamischen Wissenschaften* 9 (1994): 161-194.

Kuntz, Marion L. *Guillaume Postel – Prophet of the Restitution of All Things: His Life and Thought*. The Hague: Martinus Nijhoff, 1981.

Latour, Bruno, and Steve Woolgar. *Laboratory Life: The Construction of Scientific Facts*. Princeton, NJ: Princeton University Press, 1986.

Lohlker, Rüdiger. "Reflections on Science and Religion in Islam." In *Voices of Three Generations: Essays in Honor of Seyyed Hossein Nasr*, edited by Mohammad A. Faghfoory and Katherine O'Brien, 217-223. Chicago, IL: Kazi Publications, 2019.

Lu Yongxiang, ed. *A History of Chinese Science and Technology*, vol 1. Heidelberg: Springer/ Shanghai Jiao Tong University Press, 2015.

Ma, I. *Islamic Science of Astronomy and Calendrical Technology in the Medieval China and Significant Contribution to the Chinese Science of Astronomy and Calendrical Technology in the Chinese Northern Sung Dynasty.* Academia. Accessed November 11, 2018, https://www.academia.edu/5918944/Islamic_Science_of_Astronomy_and_Calendrical_Technology_in_the_Medieval_China_and_Significant_Contributions_to_the_Chinese_science_of_astronomy_and_Calendrical_Technology_in_the_Chinese_Northern_Sung_Dynasty.

Mekking, Aart, and Eric Roose, eds. *The Global Built Environment as a Representation of Realities: Why and How Architecture Should Be Subject of Worldwide Comparison*. Utrecht: Pallas Publications, 2009.

Morrison, Robert G. "What was the Purpose of Astronomy in al-Ījīs *Kitāb al-Mawāqif fī ʿilm al-kalām*." In *Politics, Patronage and the Transmission of Knowledge in 13th-15th Century Tabriz*, edited by Judith Pfeiffer, 201-229. Leiden: Brill, 2013.

_____. "*Falsafa* and Astronomy after Avicenna: An Evolving Relationship." In *Avicenna and his Legacy: A Golden Age of Science and Philosophy,* edited by Y. Tzvi Langermann, 307-326. Turnhout: Brepols, 2009.

_____. *Islam and Science: The Intellectual Career of Nizam al-Din al-Nisaburi*. London: Routledge, 2007.

Needham, Joseph. "The Peking Observatory in A.D. 1280 and the Development of the Equatorial Mounting." *Vistas in Astronomy* 1 (December 1955): 67-83.

Niazi, Kaveh. *Qutb al-Din Shirazi and the Configuration of the Heavens: A Comparison of Texts and Models*. Dordrecht: Springer, 2014.

Niri, Javad Shekari. "An Inquiry into Maragheh Observatory: The First International

Scientific-Research Foundation of the Ilkhanid Era." *International Journal of Humanities* 25 (2018): 77-93.

Panaino, Antonio. "Sasanian Astronomy and Astrology in the Contribution of David Pingree." In *Kayd: Study of Mathematics, Astronomy and Astrology in Memory of David Pingree*, edited by Gherardo Gnoli and Antonio Panaino, 73-103 Rome: Istituto Italiano per l'Africa e l'Oriente, 2009.

Parr, Adrian, ed. *The Deleuze Dictionary*. Edinburgh: Edinburgh University Press, 2005.

Perlus, Barry. *Architecture in the Service of Science: The Astronomical Observatories of Jai Singh* II. Jamantar.org. Accessed November 10, 2018. http://www.jantarmantar.org/Architecture _Science_ web.pdf.

Petitjean, Patrick, Catherine Jami, and Anna Marie Moulin, eds. *Science and Empires: Historical Studies about Scientific Development and European Expansion*. Dordrecht: Springer, 1992.

Rageb, F. Jamil. "The *Khilāṣ kayfiyyat tarkīb al-aflāk* of al-Jūzjānī." In *Avicenna and his Legacy: A Golden Age of Science and Philosophy*, edited by Y. Tzvi Langermann, 301-306. Turnhout: Brepols, 2009.

_____. "Copernicus and his Islamic Predecessors: Some Historical Remarks." *History of Science* 45, no. 1 (2007): 65-81.

_____. "ʿAli Qushji and Regiomantanus: Eccentric Transformations and Copernican Revolutions." *Journal for the History of Astronomy* 36 (2005): 359-371.

_____. "Freeing Astronomy from Philosophy: An Aspect of Islamic Influence on Science." *Osiris* 16 (2001): 49-64, and 66-71.

_____. *Nasir al-Din al-Tusi's Memoir on Astronomy (al-Tadhkira fi 'Ilm al-Hay'a), with translation and commentary*, 2 vols. New York: Springer, 1993.

Ragep, Sally P. *Jaghmīnī's Mulakhkhaṣ: An Islamic Introduction to Ptolemaic Astronomy*. Dordrecht: Springer, 2016.

Rashed, Roshdi, and Régis Morelon, eds. *Encyclopedia of the History of Arabic Science*. vol 1: *Astronomy – Theoretical and Applied*. London: Routledge, 1996.

Rheinberger, Hans-Jörg. *On Historicizing Epistemology: An Essay*. Stanford, CA: Stanford University Press, 2010.

Sabra, Abdelhamid I. "On Seeing the Stars, II. Ibn al-Haytham's 'Answers' to the 'Doubts' Raised by Ibn Maʿdān." *Zeitschrift für die Geschichte der Arabisch-Islamischen Wissenschaften* 10 (1995/96): 1-59.

Saliba, George. "Cometary Theory and Prognostications in the Islamic World and their Relationship to Renaissance Europe." In *The Occult Sciences in Pre-modern Islamic Cultures*, edited by Nader El-Bizri and Eva Orthmann, 105-134. Beirut: Ergon Verlag i. Komm., 2018.

_____. *Islamic Science and the Making of the European Renaissance*. Cambridge, MA: MIT Press, 2007.

_____. "The Rôle of Maragha in the Development of Islamic Astronomy: A Scientific Revolution before Renaissance." *Revue de Synthèse* 108, no. 3-4 (1987): 361-373.

Schmidl, Petra G. "ʿUrḍī: Muʾayyad (al-Milla wa-) al-Dīn (Muʾayyad ibn Barīk [Burayk]) al-ʿUrḍī (al-ʿĀmirī al-Dimashqī)." In *The Biographical Encyclopedia of Astronomers*, edited by Thomas Hockey, Virginia Trimble, Thomas R. Williams, Katherine Bracher, Richard A. Jarrell, Jordan D. Marché II, JoAnn Palmeri, and Daniel W. E. Green, 1161-1162. New York: Springer, 2007.

Tekeli, Sevim. "*Al-'Urdī's Article on 'the Quality of Observation'.*" Foundation for Science Technology and Civilization. Accessed October 8, 2018. http://www.muslimheritage.com/uploads/Al_Urdi_Article.pdf.

Thoren, Victor E. *The Lord of Uraniborg: A Biography of Tycho Brahe*. Cambridge: Cambridge University Press, 1990.

Vagelpohl, Uwe. *Aristotle's "Rhetoric" in the East: The Syriac and Arabic Translation and Commentary Tradition*. Leiden: Brill, 2008.

Van Dalen, Benno. "Ulugh Begh: Muḥammad ibn Ṭaraghāy ibn Shāhrukh ibn Tīmūr." In *The Biographical Encyclopedia of Astronomers*, edited by Thomas Hockey, Virginia Trimble, Thomas R. Williams, Katherine Bracher, Richard A. Jarrell, Jordan D. Marché II, JoAnn Palmeri, and Daniel W. E. Green, 81-96. New York: Springer, 2007.

_____. "Islamic and Chinese Astronomy under the Mongols: a Little-Known Case of Transmission." In *From China to Paris: 2000 Years Transmisson of Mathematical Ideas*, edited by Yvonne Dold-Samplonius, Benno van Dalen, Joseph W. Dauben, and Menso Folkerts, 327-356. Stuttgart: Franz Steiner, 2002.

Van Ess, Josef. *Die Erkenntnislehre des ʿAḍud al-Dīn al-Ījī.* Wiesbaden: Harrassowitz, 1966.

Yabuuti, Kiyoshi. "The Influence of Islamic Astronomy in China." In "From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy," edited by David King and George Saliba. Special issue, *Annals of the New York Academy of Sciences* 500, no. 1 (1987): 547-559.