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# AḤMAD AL-FARGHĀNĪ AND HIS *COMPENDIUM OF ASTRONOMY*

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Abū l-'Abbās Aḥmad b. Muḥammad b. Kathīr al-Farghānī (Alfraganus in Latin) was a major figure among the early medieval astronomers, mathematicians, and geographers. Through his works he played an important role in transmitting Islamic scientific knowledge to the West. In this article I have tried to establish some facts about al-Farghānī's life and works, as little information about him has been preserved in the medieval sources.[1] I have also included an introduction to one of his main astronomical works, the *Compendium of Astronomy and the Principles of Celestial Motions* (*Jawāmi' 'ilm al-nujūm wa-uṣūl al-ḥarakāt al-samāwiyya*), which has not yet been fully translated into any modern language. In the modern scientific literature this work by al-Farghānī is also known as the *Elements of Astronomy*.

Al-Farghānī's scientific reputation and scholarly endeavours are acknowledged by Fuat Sezgin, who quotes from the French scholar Pierre Duhem:

> Everything which Robert Grosseteste, a leading figure in the thirteenth-century Aristotelian school of Paris, attributed to Ptolemy in his *Summa Philosophiae* was in fact taken from al-Farghānī. We note further that the Italian astronomers from the thirteenth until the beginning of the fourteenth century depended completely upon the book of al-Farghānī when they referred to Ptolemy. This is the case, for instance, with Ristoro d'Arezzo and his *Della composizione del mondo*. All of his ideas are from the book of al-Farghānī, in spite of the fact that he refers to Ptolemy without having any acquaintance with the *Almagest*. Similar facts are known concerning the influence of al-Farghānī upon the famous Italian poet Dante Alighieri, who also obtained all the Ptolemaic astronomical ideas in his *Il convivo* from the book of al-Farghānī. Finally, I mention that Regiomontanus, the famous Renaissance scholar, delivered lectures in Padua in 1464 based on al-Farghānī's book.[2]

[1] Biographical and bibliographical data on al-Farghānī are given by A. I. Sabra, 'al-Farghānī', *Dictionary of Scientific Biography* (New York, 1971), vol. 4, pp. 541–5. See also G. Sarton, *Introduction to the History of Science* (Baltimore, MD, 1927), vol. 1, p. 567. For lists of his works and available manuscripts, see F. Sezgin, *Geshichte des arabischen Schrifttums* (Leiden, 1974), Band V, pp. 259–60; Band VI, pp. 149–51.



Although al-Farghānī is well known in the history of medieval science, the available information on his life and scientific activity is very limited and often contradictory; even his full name and dates of birth and death are uncertain. His last name, al-Farghānī, establishes a link with Farghana and shows that it is quite likely that he was born there.[3]

According to A. Ahmedov's calculation, al-Farghānī was probably born in the year AD 797–8, a suggestion which he justifies as follows:

> If we accept that the caliph al-Ma'mūn shifted his court from Merv to Baghdad in AD 819, and if we assume that Aḥmad al-Farghānī was one of the scholars who followed al-Ma'mūn to his new capital in Baghdad, the age of al-Farghānī, at that time, might be between 20 and 25 years. This age seems likely, as al-Farghānī must have needed 20–25 years for his primary education and to become a scholar. The latest reference to al-Farghānī mentions that he was alive in 861. It is possible that he did not live long after this date and died sometime in 865. If we assume that Aḥmad al-Farghānī was in his mid-twenties in 819, and that he died sometime in 865 at the age of 67 or 68, then we would probably be right in assuming that he was born in 797 or 798.[4]

We may therefore suggest that the 1200th anniversary of the birth of Aḥmad al-Farghānī occurred in the year 1997 or 1998.

Several medieval Arabic sources contain information on al-Farghānī and his works. For example, Ibn an-Nadīm (d.993) in his *al-Fihrist* mentions that 'his name was Aḥmad b. Muḥammad b. Kathīr. He was a distinguished man and a leading astrologer. Among his works were *Selections (Chapters) from the Almagest* and *The Construction of Sundials*.'[5]

Ibn al-Qifṭī (1173–1248) believes that Aḥmad b. Muḥammad b. Kathīr al-Farghānī was one of al-Ma'mūn's astronomers and that he wrote *Introduction to the Science of Astronomy and Motions of the Stars* (*Al-madkhal ilā 'ilm hay'at al-aflāk wa-ḥarakāt al-nujūm*). According to Ibn al-Qifṭī, this useful work, consisting of 30 chapters, presents a compendium of Ptolemy's *Almagest* in a pleasant style and with clear

[2] F. Sezgin, *Aḥmad b. Muḥammad b. Kathīr al-Farghānī: Jawami' 'ilm al-nujūm wa uṣūl al-ḥarakāt al-samāwīya* (Frankfurt, 1986), vi.

[3] The valley of Farghana, with an area of 300 km by 22,000 km, is mostly situated in Uzbekistan and surrounded by parts of the Tian-shan mountains to the north and the Hisar-Alay mountains to the south. Some parts of the valley are situated in modern-day Kyrgyzstan and Tajikistan.

[4] A.A. Ahmedov, 'Aḥmad al-Farghāni', in M. M. Khairullaev (ed.), *Buyuk siymolar, allomalar* (*Outstanding Figures, Scholars*) (Tashkent, 1995), vol. 1, p. 18 (in Uzbek).

[5] B. Dodge (ed. and tr.), *The Fihrist of al-Nadīm. A Tenth-Century Survey of Muslim Culture* (New York and London, 1970), vol. 2, p. 660.

explanation.[6] Ibn al-Qifṭī then goes on to talk about another Muḥammad b. Kathīr al-Farghānī (assuming that he was the father of Aḥmad al-Farghānī), who was distinguished in astronomy and who wrote books such as the *Book of Aphorisms* (*Kitāb al-fuṣūl*), *The Abridged Almagest* (*Kitāb ikhtiṣār al-Majisṭī*), and *The Construction of Sundials* (*Kitāb 'amal al-rukhāmāt*).[7]

Modern historians of science are agreed that two scholars given different names (Muḥammad b. Kathīr and Aḥmad b. Muḥammad b. Kathīr) in the sources may actually be identified with one and the same scholar: Abū l-'Abbās Aḥmad b. Muḥammad b. Kathīr al-Farghānī.[8] Thus, over time, Ibn Qifṭī's belief in the existence of two al-Farghānīs—a father, Muḥammad b. Kathīr, and a son, Aḥmad b. Muḥammad b. Kathīr—has lost favour.

Regarding al-Farghānī's contribution to the construction of the Nilometer and digging a canal, Ibn Abī Uṣaybi'a (1194–1270) and Ibn Tagrī Birdī (1411–70) have recorded the following information in their books. The Nilometer was an instrument for measuring the height of water in the river Nile during floods; it was built in AD 750 at the southern end of Rawḍa island in Egypt and subsequently rebuilt in AD 861. These sources mention that Aḥmad b. Kathīr al-Farghānī (according to Ibn Abī Uṣaybi'a) or Muḥammad b. Kathīr al-Farghānī (according to Ibn Tagrī Birdī) participated in the construction of the Nilometer and canal. Ibn Abī Uṣaybi'a says that the caliph al-Mutawakkil ordered two scholars, the brothers Muḥammad and Aḥmad, sons of Mūsā b. Shākir, to dig a canal known as 'al-Ja'fariyya'. Muḥammad and Aḥmad handed over the work to Aḥmad b. Kathīr al-Farghānī, who constructed the new measuring instrument in Egypt. His effort was hampered by bad luck, however, and he never completed the work, because he made a mistake in sloping the canal and keeping its mouth lower than the rest of it. As a result, whatever passed into the mouth of the canal did not flow properly to its other parts. Muḥammad and Aḥmad (the sons of Mūsā) attempted to conceal this error which was made by al-Farghānī. When he learned about the situation, al-Mutawakkil announced that if it was confirmed that the two brothers had delegated the work to al-Farghānī, who then committed the error, he would crucify both brothers. He appointed Sanad b. 'Alī from Baghdad (Madīnat al-Salām) as the consultant to investigate the matter. Sanad b. 'Alī reached an unofficial agreement with the brothers, and declared that no mistake had been made. The error, if there was one, would be visible in four months when the surface level of the water would

[6] See J. Lippert (ed.), *Ibn al-Qifṭī's Ta'rīkh al-ḥukamā'* (Leipzig, 1903), 78.
[7] Ibid. 286.
[8] F. Rosenthal, 'al-Farghānī', *EI*², vol. 2 (Leiden, 1991), 793.



decline.[9] Although no other record survives of al-Farghānī's work on this matter, we do know that al-Mutawakkil died soon after he had ordered the construction of the canal.

On the subject of al-Farghānī and the Nilometer, Ibn Tagrī Birdī writes that in 861 the caliph al-Mutawakkil built a measuring instrument or New Nilometer (known as *al-miqyās al-jadīd*) in Fusṭāṭ (Old Cairo). For this, al-Mutawakkil summoned 'the engineer' (*al-muhandis*) Muḥammad b. Kathīr al-Farghānī from Iraq, who took charge of its construction. Al-Mutawakkil ordered Christians (Copts) to end the practice of measuring with the Nilometer, and Yazīd b. 'Abdallah, governor of Egypt, appointed 'Abdallah b. 'Abd as-Salām Abū Raddād for this task.[10]

Abū l-Faraj bar Hebraeus (1226–86) mentions al-Farghānī as an astronomer during the time of the caliph al-Ma'mūn and refers to his *Compendium*.[11] However, as previously mentioned, Ibn Abī Uṣaybi'a and Ibn Tagrī Birdī report his presence during the time of the caliph al-Mutawakkil (847–61), who sent al-Farghānī to Fusṭāṭ to supervise the construction of the Nilometer (*al-miqyās al-kabīr*) in 861. This means that al-Farghānī was among the scholars who lived during the times of several previous caliphs, namely al-Ma'mūn (813–33), al-Mu'taṣim (833–42), and al-Wāthiq (842–7). No information, however, is available about al-Farghānī during the reigns of the caliphs al-Mu'taṣim and al-Wāthiq.

In the context of the Rawḍa Nilometer, another medieval bibliographer, Ibn Khallikān (1211–82), mentions al-Farghānī under the name of Aḥmad b. Muḥammad al-Qarṣānī.[12] The last name, here, without any doubt, refers to al-Farghānī. Ibn Khallikān's orthographic mistake is quite understandable from the palaeographical point of view, as the written form of the two names in Arabic is quite similar.

Another name for the constructor of the Nilometer—Aḥmad al-Farghānī—appears in B. T. A. Evetts's book on *The Churches and Monasteries of Egypt* as Ibn Kātib al-Farghānī. Referring to the *Guide to the Festivals*, he says that 'on the 7th of Kihak, Ibn Kātib al-Farghānī was beheaded. He was the one who had supervised the construction of the Nilometer in AH 247. He was buried in the church of Saint

[9] A. Muller (ed.), Ibn Abī Uṣaybi'a, *Ṭabaqāt al-aṭibbā'* (Cairo, 1882), vol. 2, p. 207.
[10] T. G. J. Juynboll (ed.), Abū al-Maḥāsin Ibn Tagrī Birdī, *al-Nujūm al-ẓāhira fī mulūk Miṣr wa al-Qāhira* (Leiden, 1851), vol. 2, p. 742. For a short biography of Ibn Raddād, see Ibn Khallikān, *Kitāb wafayāt al-a'yān*, translated from the Arabic by B. N. MacGuckin De Slane (Paris, 1843–71), vol. 2, p. 75.
[11] Ibn al-'Ibrī, *Ta'rīkh mukhtaṣar al-duwal* (Beirut, 1890), 236.
[12] A.I. Sabra, 'al-Farghānī', 541.

Coluthus...'[13] Later, on the basis of Stanley Lane-Poole's[14] opinion that the mosque of Ibn Ṭūlūn and the Nilometer were probably built by the same architect, Evetts reached the conclusion that the Nilometer was probably built by Ibn Kātib al-Farghānī, the Coptic architect of the Nilometer. This deduction however was based on the uncertain fact that the builder of Ibn Ṭūlūn's mosque was known to be a Copt. This burial of al-Farghānī in the church of Saint Coluthus and his description as a Copt would certainly bring a new dimension to his biography, if it can be established that all this information refers to one and the same person. As a matter of fact, there were several other scholars with the name of al-Farghānī. This apparent confusion over the identity of Aḥmad al-Farghānī can only be removed by further research.

Al-Bīrūnī (973–*c.*1050) also provides some information about the life of al-Farghānī. According to him, Muḥammad al-Khwarizmī and Yaḥyā b. Abī Manṣūr in Baghdad and Khālid al-Marwarrūdhī and Aḥmad al-Farghānī in Damascus carried out astronomical observations. Al-Bīrūnī also noted that al-Farghānī participated in the scientific expedition that took place between 820 and 833 in Tadmor and Raqqa on the plain of Sinjār in Syria.[15] The main purpose of this expedition was to examine the actual length of one degree of a meridian, which had been calculated by Ptolemy. As we know, the length was established as $56\frac{2}{3}$ miles in al-Farghānī's book and this result was deemed to be the most accurate value of the true length of a degree of a meridian. Al-Bīrūnī again mentions al-Farghānī in connection with the projection of star maps.[16]

Aḥmad al-Marwazī, also known as Ḥabash al-Ḥāsib, one of the early medieval astronomers of the ninth century, refers to al-Farghānī's book on the construction of an astrolabe.[17]

## THE *COMPENDIUM OF ASTRONOMY*

Seven works by Aḥmad al-Farghānī survive. They are listed in the appendix to this article. His most important and famous work is the *Compendium of Astronomy and the Principles of Celestial Motions* (*Jawāmiʿ ʿilm al-nujūm wa-uṣūl al-ḥarakāt al-samāwiyya*). The first

[13] See B. T. A. Evetts (ed. and tr.), *The Churches and Monasteries of Egypt and some Neighbouring Countries* (Oxford, 1895), 114.

[14] S. Lane-Poole, *A History of Egypt in the Middle Ages* (London, 1901).

[15] A.A. Ahmedov, op. cit. 18.

[16] E. Savage-Smith, 'al-Bīrūnī on Celestial Mapping', in J. B. Harley and D. Woodward (eds.), *The History of Cartography*, vol. 2, book 1: *Cartography in the Traditional Islamic and South Asian Societies* (Chicago, IL, 1992), 34.

[17] See J. Golius, *al-Farghānī* (Amsterdam, 1669), 67.



scholar to take an interest in this work was John of Spain, who translated it from Arabic into Latin under the title *Differentie scientie astrorum* around 1137. Before 1175 Gerard of Cremona made a second Latin translation under the title *Liber de aggregationibus scientiae stellarum et principiis celestium motuum*. The Hebrew translation of al-Farghānī's *Compendium* made by Jacob Anatoli in 1231 was printed in 1618 under the title *Muhamedis Alfragani Arabis Chronologica et astronomica elementa, e Palatinae Bibliothecae veteribus libris versa, expleta, et scholiis expolita. Additus est Commentarius, qui rationem calendarii Romani, Aegyptiaci, Arabici, Persici, Syriaci et Hebraei...*[18] In 1590, at Frankfurt-am-Main, Jacob Christmann made a third Latin translation of the book on the basis of its Hebrew version by J. Anatoli and of the previous two Latin translations. John of Spain's translation was printed in Ferrara as early as 1493, and then reprinted in Nuremberg (Ph. Melanchthon's edition of 1537), Paris (1546), and Berkeley (J. Carmody's edition of 1943). Gerard of Cremona's translation was printed only in 1910.

The best-known and most important edition of al-Farghānī's *Compendium* is by Jacob Golius. In 1669 in Amsterdam he published the Arabic text together with his own Latin translation under the title *Muhammedis Fil. Ketiri Ferganensis, Qui vulgo al-Fraganus dicitur, Elementa Astronomica, Arabice & Latine. Cum notis ad res exoticas sive Orientales, qua in iis occurrunt.*

In 1986, in Frankfurt-am-Main, F. Sezgin reprinted Golius's edition with a short preface in English and Arabic. But F. Sezgin did not publish Golius's comments on the *Compendium*, although Golius had supplemented his edition with more than 150 pages of detailed commentaries on the first nine chapters, while the Latin text of the *Compendium* itself occupies only about sixty pages. One of the Arabic manuscripts of the *Compendium* preserved at the Bodleian Library, Oxford (MS. Arch. Seld. A.11), dated 687/1288, is apparently the second oldest copy of the *Compendium*, the oldest being in Istanbul (Ayasofya MS. 2843/2), which is dated 672/1243. Also preserved at the Bodleian is a copy of the printed text of John of Spain's edition (1493) under the title *Breuis ac perutilis compilatio Alfragani astronomorum pertissimi totum id continens quod ad rudimenta astronomica est opportunum*[19] and J. Golius's edition of the *Compendium*.[20] A comparison of Golius's edition of the *Compendium* with its manuscript at the Bodleian Library shows that

[18] A. I. Sabra, op. cit. 544.

[19] The printed text was (incorrectly) given the shelfmark MS. Ashmole 124, as if it were a manuscript.

[20] Shelfmark Sem. 3.441.

they are not always identical; and in some cases the difference between them is considerable. The most important differences are summarized below.

Despite being widely used and having been translated several times into Latin and Hebrew during the Middle Ages, the *Compendium* by al-Farghānī still lacks a complete translation into any modern language.

The *Compendium* was written between 833 and 861. It is a short introductory course in astronomy based on Ptolemy's *Almagest*, comprising about seventy pages and thirty chapters. For this reason in some sources it is referred to as a book of thirty chapters. Speaking about the significance of the book in the history of astronomy, Sezgin writes that 'This book marks the beginning of the period during which Arab astronomers introduced new elements into the science of astronomy, and exhibited an attitude of healthy scepticism and caution toward the contents of Ptolemy's works.'[21]

In his book al-Farghānī describes the main subjects of astronomy, which are the heavens, the planets, the stars, the sun, the moon, and the earth, and their movements and the different astronomical determinations concerning them; he also provides a list of the well-known lands and cities. He tried to present his book in a simple style without complicated mathematical calculations. This fact played a considerable role in its adoption as a basic manual in astronomy.

Of course, al-Farghānī's main authority was the *Almagest* by Ptolemy. Only once does he mention the name of another medieval scholar, Yaḥyā b. Abī Manṣūr (chapter 5),[22] although he often uses phrases like 'as accepted by scholars' or 'scholars of our time', without actually giving their names. For this reason it is difficult to determine his main sources apart from the *Almagest*. But we can assume that he was familiar with the majority of the astronomical works composed during the time of al-Ma'mūn and used them widely in compiling the *Compendium*.

In order to present a clear picture of al-Farghānī's *Compendium* which has never been fully translated into English,[23] we briefly discuss below the contents of its chapters. A short summary of some of the differences between the manuscripts in the Bodleian Library (MS. Arch. Seld. A.11, ff. 3[b]-37[b]) and in Leiden (Sem. 3.441), published by J.Golius, is also provided.

[21] F. Sezgin, *al-Farghānī*, v.

[22] Yaḥyā b. Abī Manṣūr, one of the co-ordinators of the astronomical works carried out during the reign of al-Ma'mūn in Baghdad and Damascus, died in 217/832.

[23] A. I. Sabra gives a short summary of the contents of the *Compendium*, op. cit. 542–3.



## SUMMARY

**Chapter 1. On the Arabic and foreign years (the Syrian, Roman, Persian, and Egyptian calendars) and the differences between them.** Al-Farghānī discusses the years, months, and days used by different peoples and describes the differences between them. The Leiden manuscript begins with the Arabic calendar while the Bodleian copy begins with the Persian. The description of the leap year (*kabīsa*), in particular, and the month of February (*shubāṭ*) in the Leiden manuscript is different from that in the Bodleian manuscript. In the latter on folio 5[a] there are the words 'another copy' (*nuskha ukhrā*) written in red ink, which is exactly similar to the description of February in the Leiden manuscript. This means that the scribe of the Bodleian manuscript in all probability compared his exemplar with other copies. There are also differences in the names of Coptic months between the two manuscripts.

**Chapter 2. On the sphericity of the heavens and their rotation.** The author justifies the sphericity of the heavens saying that there is no doubt among scholars on this matter and giving examples to describe it.

**Chapter 3. On the sphericity of the earth.** Al-Farghānī justifies the sphericity of the earth on the evidence that the sun, the moon, and the stars rise and set in different parts of the world at different times.

**Chapter 4. On the fact that the terrestrial globe is in the centre of the heavens and that its size in relation to the heavens is as small as the point in a circle.** Al-Farghānī indicates the central position of the earth, giving some examples, and justifies it on the evidence that each part of the earth is visible from the sky at exactly the same distance.

**Chapter 5. On the two primary movements of the heavens: the universal movement of everything from east to west and the movement of the stars (sun, moon, and planets) from west to east.** Al-Farghānī says that we can recognize two movements in the heavens: the first of them (*ḥarakat al-kull*) is from east to west and the second (*ḥarakat al-kawākib*) is from west to east. After this he explains that the zodiac is divided into twelve equal parts and gives their names: Aries (al-Ḥamal), Taurus (al-Thawr), Gemini (al-Jawzā'), Cancer (al-Saraṭān), Leo (al-Asad), Virgo (al-Sunbula), Libra (al-Mīzān), Scorpio (al-'Aqrab), Sagittarius (al-Qaws), Capricorn (al-Jady), Aquarius (al-Dalw), Pisces (al-Ḥūt). He states that each sign of the zodiac is divided into 30 degrees and therefore the circle consists of 360 degrees. There are no differences between the Ptolemaic value for the obliquity of the ecliptic 23°51′ and the value determined during the time of al-Ma'mūn 23°35′ in the two manuscripts. But the Bodleian manuscript states that al-Ma'mūn's value was determined by the established scholar Yaḥyā b. Abī Manṣūr and agreed upon by other scholars.

**Chapter 6. On the inhabited quarter of the earth and a summary of the events in the inhabited part of the earth during the movement of the heavens and the differences between night and day.** Al-Farghānī begins this chapter with explanations of the Equator, that divides the earth into two parts, and the South and North Poles. After that, he speaks about the location of the inhabited part of the earth, the horizon, meridian, and differences between summer and winter as well as between day and night at both of the Poles.

**Chapter 7. On the characteristics of the inhabited quarter (of the earth) and the places where the sun rises for (several) months without setting and where it sets for (several) months without rising.** The author explains the features of places between the Equator and the limits of inhabited part of the earth and the appearance of the sun in other parts.

**Chapter 8. On the land surface and its division into seven inhabited (*al-ʿāmira*) climes.** Al-Farghānī details the main measurements of the earth and the seven climes. There are differences in the value of one degree of a meridian between the Leiden and Bodleian manuscripts. In the Leiden manuscript one degree of a meridian is established as $56\frac{2}{3}$ miles while the Bodleian manuscript refers to it as $66\frac{2}{3}$ miles. Moreover, the scribe of the Bodleian manuscript puts the numerical value of one degree above its descriptive value. This suggests that the scribe was familiar with another copy of the *Compendium* with the value $56\frac{2}{3}$ miles and that he wished to confirm the former value ($66\frac{2}{3}$) in his copy. Multiplying $66\frac{2}{3}$ miles by 360, al-Farghānī finds the circumference of the earth to be 24,000 miles; and dividing 24,000 by 3.7 he gives the approximate diameter of the earth as 6,600 miles. But we must note that all these calculations in the Bodleian manuscript are incorrect if we compare them with those in the Leiden copy. The measure $66\frac{2}{3}$ miles, which was used as the basis for further astronomical and geographical calculations, was criticized by Carlo Nallino who said that several Arab scholars introduced an error in the translation of Ptolemaic measurements from Greek and Syriac sources into Arabic. Their error was that they did not take into account that Roman and Syriac miles are shorter than Arabic miles. As a result 24,000 Arabic miles (which is $66\frac{2}{3}$ miles multiplied by 360) for the circumference of the earth became equal to 47,352 km, while the Ptolemaic value is only 38,340 km. Carlo Nallino considered $56\frac{2}{3}$ miles (111 km) to be a more accurate figure.[24] Thus, in this particular case, the data of the Leiden manuscript are

[24] C. Nallino, *ʿIlm al-falak wa-taʾrīḫuhu ʿind l-ʿArab fī l-qurūn al-wusṭā* (Roma, 1911), 279 (in Arabic). See also R. P. Mercier, 'Measurements of the Length of a Degree', in J. B. Harley and D. Woodward (eds.), *The History of Cartography*, vol. 2, book 1: *Cartography in the Traditional Islamic and South Asian Societies* (Chicago, IL, 1992), 178–81.



more correct regarding both the circumference of the earth (20,400 miles) and its diameter (6,500 miles) and radius (3,250 miles). In this chapter al-Farghānī also divides the inhabited part of the earth into seven climes and describes them. The seven-clime system of al-Farghānī was recently published by Gerald R. Tibbetts.[25]

**Chapter 9. On the names of the well-known lands and cities in each clime.** This begins with an explanation of such geographical terms as longitude and latitude of the cities; al-Farghānī then mentions a number of cities situated in each clime and supplies information about their geographical locations. We should note that several textual differences exist regarding the names of the cities between the Bodleian and Leiden manuscripts. For example, cities like Maʾrib and Bairūt in the Bodleian manuscript are given as Mārā and Bairūn in the Leiden manuscript.

**Chapter 10. On the ascension of the signs of the zodiac and their differences in the right and oblique spheres.** The author discusses right spheres (*aflāk mustaqīma*), that is horizons of the Equator, and oblique spheres (*aflāk māʾila*), that is horizons of the climes, and explains the rising and setting of the signs of the zodiac in both of them.

**Chapter 11. On the length of the day and the night and differences between equal and temporal hours.** This concerns the periods of day and night and equinoctial (*muʿtadila*) and unequal (*zamāniyya*) hours.

**Chapter 12. On the description of the spheres of the planets, their configuration, and distances from the earth.** The author describes fixed (*thābita*) stars and moving (*jāriya*) stars (i.e. planets), their spheres, and distances from the earth. He states that he follows the opinions of previous scholars in this matter, but he does not indicate the precise source from which he draws his data. According to him there are seven moving stars (planets) and the circle of the zodiac, all encompassed by the moving stars. He lists distances between the spheres of each planet in the following order: the smallest and nearest to the earth is the sphere of the moon; after that, the spheres of Mercury, Venus, the sun, Mars, Jupiter, Saturn; and after them the sphere of the fixed stars follows. He also explains such astronomical terms as 'belt of the sphere of the zodiac' (*minṭaqat falak al-burj*), 'epicycles' (*aflāk al-tadwīr*), 'eccentrics' (*aflāk khārij al-markaz*), 'apogee' (*awj*), 'perigee' (*nazīr al-awj*), and others.

**Chapter 13. On the movements of the sun, moon, and fixed stars in their spheres from the west to the east, designated as longitude movement.** Al-Farghānī begins this chapter with a description of the movements of the celestial spheres of the fixed stars and explains the reason

[25] G. R. Tibbetts, 'The Seven Climates and their Boundaries' in *The History of Cartography*, 102.

why these stars are regarded as being fixed. Then he gives information about two movements of the sun and five circular movements of the moon in longitude.

**Chapter 14. On the movement of the five 'wandering' (*mutaḥayyira*) planets in their celestial spheres in longitude.** This contains a detailed description of the four visible movements of the planet Mercury and three visible movements of the planets Venus, Mars, Jupiter, and Saturn during their course through the circle of the zodiac.

**Chapter 15. On the retrograde motions of the five 'wandering' planets in the zodiac.** This is about retrograde movements of the planets Mercury, Venus, Mars, Jupiter, and Saturn. The author also explains why they are described as 'wandering'.

**Chapter 16. On the values of eccentricities and epicycles.** This is devoted to the magnitudes of the eccentricities of the sun, the moon, Mercury, Saturn, Jupiter, Mars, and Venus.

**Chapter 17. On the movement of the planets in their orbits and the circle of the zodiac.** This is a discussion about approximate values of the rotation of the sun, the moon, Mercury, Saturn, Jupiter, Mars, and Venus.

**Chapter 18. On the movement of the fixed and 'moving' (*jāriya*) stars in a north-south direction designated as latitude movement.** Al-Farghānī describes latitude movement as a declination of the planets from the zodiac towards the north and south and gives the latitude movements of the fixed stars, the sun, moon, and five 'wandering' planets.

**Chapter 19. On the number of the fixed stars and their classification according to their magnitude and a description of the fifteen stars of greatest magnitude.** Al-Farghānī informs the reader that scholars had measured the fixed stars and divided them into six groups according to their magnitude. They are as follows: the first magnitude 15 stars, the second 45 stars, the third 208 stars, the fourth 474 stars, the fifth 217, and the sixth 63 stars. The total number of the measured stars is 1022. Among them, 360 stars are situated on the north side of the belt of the zodiac, 316 stars are on the south side of the zodiac, and 346 stars in the heart (*ṣadr*) of the zodiac. After that al-Farghānī lists the fifteen most visible stars from the first group and provides detailed explanations about their locations.

**Chapter 20. On the description of the twenty-eight stars called stations of the moon (or lunar mansions, *manāzil al-qamar*).** Al-Farghānī begins this chapter with the words: 'We describe here lunar mansions with the names given them by the Arabs. This is because the majority of people know them by these names.' After that he lists twenty-eight names of the lunar mansions with the particular stars situated in each.

**Chapter 21. On the distance of the moving and fixed stars from the earth.** Al-Farghānī says: 'In his book Ptolemy describes only the distance of the moon and the sun without mentioning the distance of the other planets... Ptolemy and other scholars took the radius of the earth as the unit of measure for the distance of the planets from the centre of the earth, and they used the mass of the earth to aid them in measuring the masses of the planets. As already stated, the diameter of the earth is 6,500 miles [but in chapter 8 al-Farghānī mentions 6,600 miles] and therefore the radius of the earth that is used to measure the distances of the planets is 3,250 miles.'[26] After that al-Farghānī records his determinations of the distances of Mercury, Venus, Mars, Jupiter, and Saturn. The distances given by al-Farghānī for the apogee and perigee of the planets and their comparison with modern calculations have been published by S. H. Nasr.[27]



**Chapter 22. On the magnitudes of the planets and the size of the magnitude of the earth compared with the magnitude of each planet.** Like the last, this chapter also begins with al-Farghānī noting that Ptolemy had explained only the magnitude of the masses of the sun and moon without mentioning the masses of the other planets. He says that the determination of the masses of the other planets is easy by Ptolemy's method, and he divides the planets into groups according to their magnitude. According to al-Farghānī, the magnitude sequence of the planets is as follows: the biggest is the sun (1), followed by fifteen fixed stars (2), Jupiter (3), Saturn (4), other fixed stars (5), Mars (6), earth (7), Venus (8), the moon (9), Mercury (10).

**Chapter 23. On the differences between a star and its degree in the zodiac and during its rising and setting.** This concerns the rising and setting of the sun, the moon, the planets (Jupiter, Saturn, Mars, Venus, Mercury), and lunar mansions.

**Chapter 24. On the rising and setting of the stars and their disappearance under the rays of the sun.** This contains a short discussion about ascent, descent, and occultation of the stars and planets that depend on the speed of their movement and magnitude of their masses.

**Chapter 25. On the appearance of the new moon (half-moon, *hilāl*) and increase and decrease of the moon's light.** He describes the phases of the moon and five planets according to their position and moving speeds.

**Chapter 26. On the rising of the five planets under the rays of the sun.** This is, as the name suggests, about the ascent of the five planets—Saturn, Jupiter, Mars, Venus, Mercury.

[26] According to C. Nallino, 3250 Arabic miles is 6,410,000 metres or 3,990 English miles. See S. H. Nasr, *Science and Civilization in Islam* (Cambridge, 1968), 183. See also R. P. Mercier, 'Arabic Metrology' in *The History of Cartography*, 177.

[27] S. H. Nasr, op cit.

**Chapter 27. On the parallax of the moon and stars located near the earth.**
**Chapter 28. On the eclipse of the moon.**
**Chapter 29. On the eclipse of the sun.**
**Chapter 30. On the intervals between the eclipses of the moon and sun.** In these final chapters the author discusses traditional astronomical questions—parallax of the moon and stars, eclipses of the sun and moon, and intervals between them. According to al-Farghānī, a solar eclipse occurs when the moon reaches the point between the sun and the earth, and a lunar eclipse occurs when the earth's shadow blocks the moon's surface. He states that intervals between solar and lunar eclipses must be at least six lunar months. He also explains several cases when these intervals may be greater.

## CONCLUSION

Thus, we can say that the *Compendium* shows that Aḥmad al-Farghānī remained within the framework of the astronomical models proposed by Ptolemy in the *Almagest*. The real significance of his work lies in his commendable effort to reproduce the Arabic version of the *Almagest* and his attempts to create new elements and approaches to the science of astronomy and also to correct the contents of the *Almagest* by means of the results obtained either by himself or by other astronomers of his time. In this regard some important achievements of al-Farghānī include calculating the actual length of one degree of a meridian, established in his book as $56\frac{2}{3}$ miles, which circulated widely in Europe down to the time of Galileo. It may be mentioned, however, that in the eighth chapter of al-Farghānī's book, where the author speaks about this measurement, it is not clear whether this result was obtained by al-Farghānī himself or if he is speaking about the $56\frac{2}{3}$ miles as being obtained by the other astronomers of Caliph al-Ma'mūn's time.

Al-Farghānī states the diameter of the earth is 6,500 miles and its radius 3,250 miles and he describes how to calculate it after establishing the length of one degree of a meridian. He mentions the circumference of the earth as being 20,400 miles and counts 1,022 stars, dividing them into six groups according to their magnitude. Al-Farghānī determines the distances and sizes of the planets and provides measurements of their perigees and apogees. Detailed description of the lands and cities in his book confirms the sound geographical knowledge of its author.

The *Compendium* remained one of the most influential and widely used astronomical works in the Islamic world and Europe during the Middle Ages. This is confirmed by the large number of Arabic manuscripts of the *Compendium*, and the number of its Latin and Hebrew translations, still preserved today in many libraries around the world. Thus, his *Compendium of Astronomy and the Principles of Celestial Motions* preserves valuable information about the development of astronomy in the early ninth century throughout the Islamic world.



In conclusion, it is worth quoting Christopher Columbus's words about al-Farghānī, preserved nowadays in the Columbus library in Seville:

> Note: Sailing south from Lisbon to Guinea, I carefully noted the distance, as pilots and sailors do. Then I took the sun's elevation many times, using a quadrant and other instruments. I found myself in agreement with Alfraganus, that is to say, the length of a degree is $56\frac{2}{3}$ miles. Thus this measurement must be accepted. As a result, we are able to state that the earth's circumference at the equator is 20,400 miles.[28]

## APPENDIX

The following checklist includes all those manuscripts listed by Sezgin, with additional material where known. Several of the works, notably the first, circulated under more than one title.

1. ***Kitāb jawāmiʿ ʿilm al-nujūm wa-uṣūl al-ḥarakāt al-samāwiyya*** *(Compendium of Astronomy and the Principles of Celestial Motions)*:
Oxford, Bodleian Library, MS. Arch. Seld. A. 11 (formerly MS. Arch. Seld. 3144), folios 3b–37b, dated 687/1288.
Dublin, Chester Beatty Library, Arabic MS. 4144, dated 740/1339, 44 folios.
Cairo, Dār al-Kutub, Muṣṭafā Fāḍil *mīqāt* MS. 194/1, ff. 1a–30a, dated 876/1471.
Cairo, Dār al-Kutub, Muṣṭafā Fāḍil *majāmiʿ* MS. 47/1, ff. 1a–18a, incomplete.
Istanbul, Süleymaniye, Garullah MS. 1279/33, ff. 383b-392b, dated 883/1478.
Leiden, Universiteitsbibliothek, MS. Or. 8418/5, ff. 17–33.
Tunis, Bibliothèque Nationale, MS. 02103/1, ff. 1b–43b.
Moscow, State Library, MS. 154/2.
St. Petersburg, Institute of Oriental Studies, MS. 3059/3.[29]

[28] P. Lunde, 'al-Farghānī and the Short Degree', *Aramco World*, 43:3 (May–June 1992), 14.

[29] The two Russian copies are mentioned by G. P. Matvievskaya and B. A. Rozenfeld, *Matematiki i astronomi musalmanskogo srednevekovya i ih trudi* (Moscow, 1983), vol. 2, p. 56.

With title *Kitāb al-fuṣūl: al-Madkhal fī al-Majisṭī wa-huwa thalāthūna faṣlan*:
Istanbul, Süleymaniye, Ayasofya MS. 2843/2, ff. 61a–101b, dated 672/1273.
With title *al-Majisṭī*:
Princeton, NJ, Princeton University Library, Garrett Collection MS. 967, dated 1068/1657, 114 folios.
With title *al-ḥai'a*:
Paris, Bibliothèque Nationale, MS. Arabe suppl. 954 *bis*, item 3, ff. 116–43, dated 1174/1760.
With title *Kitāb fī uṣūl 'ilm al-nujūm*:
Cairo, Dār al-Kutub, MS. *mīqāt* 944, dated 1329/1911, 76 folios.
With title *al-Madkhal ilā 'ilm al-hai'a*:
Madalat, Morocco, Zāwīya Ḥamzawīya Collection
With title *Asmā' al-mudun wa-l-buldān al-ma'rūfa*:
Tehran, Dānishgāh, MS. 2031, ff. 471a–474a, dated 1031/1621.

2. ***Ḥisāb al-aqālīm al-sab'a*** *(Calculation of the Seven Climes)*:
Cairo, Dār al-Kutub, Muṣṭafā Fāḍil *mīqāt* MS. 194/3, f. 32r (fragment), dated 876/1471.
Gotha, Forschungsbibliothek, MS. 1523. According to F. Sezgin, this treatise is a part of al-Farghānī's *Compendium*. But D. King, referring to the copy in the Egyptian National Library, confirms that it is not a fragment of the author's first book presented under another name.[30]

3. ***Al-Kāmil fī sinā'at al-asṭurlāb al-shimālī wa-l-janūbī wa-'ilalihā bi-l-handasa wa-l-ḥisāb*** *(Complete Book on the Construction of North and South Astrolabe and its Geometrical and Arithmetical Reasons)*:
Kastamonu, Turkey, MS. 794/4, 30 folios.
Berlin, MS. 5790, ff. 1–77a, dated 900/1494.
MS. 5791, 60 folios, dated 778/1376.
MS. 5792, ff. 1–40, dated 783/1381.
MS. 5793/1, ff. 77b–79a.[31]
London, British Library, MS. Or. 5479/2.
Paris, Bibliothèque Nationale, MS. Arabe Suppl. 971 *bis*, item 5, ff. 52–91, dated 1107/1695 (Vajda 2456).
Tehran, Majlis, MS. 6411.
Tehran, Sipahsalar, MS. 702, 35 folios.
Meshed, Ridā, MS. 5593, ff. 128–156.

[30] D. A. King, *A Survey of Scientific Manuscripts in the Egyptian National Library* (Bloomington, IN, 1986), 34.
[31] W. Ahlwardt describes these four copies in his catalogue, *Verzeichniss der arabischen Handschriften* (Berlin, 1893), Band V, pp. 226–7.



Cairo, Dār al-Kutub. King provides a short note on al-Farghānī's manuscripts in the Egyptian National Library.[32] The preface to the work has been translated into German by E. Wiedemann[33] and some parts of it have been the subject of research in Russian.[34]

4. ***Kitāb 'amal al-asṭurlāb***[35] *(Book on the Construction of an Astrolabe)*:
A unique copy of this work, still largely uninvestigated and unpublished, exists in India:
Rāmpūr, Raza Library, Fihrist kutub-i 'arabī-i mawjūdah-i kutubkhānah-i riyasat-i Rāmpūr, 64.

5. ***Jadāwil al-Farghānī*** *(Tables of al-Farghānī)*:
Bankipur (=Patna), Bihar, Khudabaksh Oriental Public Library, MS. 2419/6, ff. 55–62.

5a. ***Jadāwil al-Farghānī 'alā quṭr al-jadī*** *(Al-Farghānī's tables for the diameter of the Capricorn sign of the zodiac)*:
Manisa, Turkey, MS. 1698/3, ff. 37–40.

Both 5 and 5a are still uninvestigated and unpublished. It is quite possible that these two manuscripts refer to the same treatise.

6. **Al-*Risāla fī ma'rifat al-awqāt allatī yakūn al-qamar fīhā fawq al-arḍ aw taḥti-hā***[36] *(Treatise on Recognizing the Times when the Moon is above or under the Horizon)*:
Cairo, Dār al-Kutub, MS. 194/2, 31 folios; still uninvestigated.

7. **Kitāb 'amal al-rukhāmāt** *(The Construction of Sundials)*.
Cairo, Kahrabā'i, MS. 145.
Aleppo, Qaddūr P. Sbath, MS. Suppl. 42, No. 2085.

[32] D. A. King, *A Catalogue of Scientific Manuscripts in the Egyptian National Library* (Cairo, 1981), part I, p. 387.
[33] E. Wiedemann, 'Einleitungen zu arabischen astronomischen Werken', *Weltall*, (1919–20), 216, 131–4.
[34] N. D. Sergeeva, L.M. Karpova, 'Al-Farghānī's Proof of the Basic Theorem of Stereographic Projection', translated by S. Embleton, in R. B. Thomson (ed.), *Jourdanus de Nemore and the Mathematics of Astrolabes: De Plana Spera* (Toronto, 1978), 210–17. N. D. Sergeeva, 'Traktat al-Farghānī ob astrolyabii', in *Trudi nauchnoy konferensii aspirantov Instituta estestvoznaniya i tehniki* (Moscow, 1970), 44–7. B. A. Rozenfeld, I. G. Dobrovolskii, N. D. Sergeeva, 'Ob astronomicheskiy traktatah al-Farghānī', *Istorico astronomicheskiy issledovaniya*, (1972), 191–210. N. D. Sergeeva, 'Astronomicheskiy trudi al-Khwarizmī i al-Farghānī', Avtoreferat dissertasii (Moscow, 1973) (all in Russian).
[35] C. Brockelmann, *Geschichte der arabischen Litteratur* (Leiden, 1943), Band I, p. 250.
[36] D. A. King, *A Survey*, 34.

8. ***Ta'līl li-zīj al-Khwarizmī*** *(Explanation of the Astronomical Tables of al-Khwarizmī).*

The title of this last work was mentioned by al-Bīrūnī in his book *Maqāla fī istikhrāj al-awtār*.[37] But this treatise itself no longer exists in any library.

[37] E. S. Kennedy and A. Muruwwa, 'Bīrūnī on Solar Equation', *Journal of Near Eastern Studies*, 17 (1958), 117.

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# 'ABD AL-RAḤMĀN AL-KAWĀKIBĪ'S REFORMIST IDEOLOGY, ARAB PAN-ISLAMISM, AND THE INTERNAL OTHER[1]

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The second half of the nineteenth century witnessed an acceleration of the rate of change within the Ottoman empire along with a greater interconnectedness with Europe, its peoples, technologies, and ideas. Namik Kemal, Muḥammad 'Abduh, and Jamāl al-Dīn al-Afghānī were among the early thinkers who absorbed the new ideas emanating from Europe and transformed them into an Islamic idiom. Their reformist ideas found an echo among various constituencies and intellectual traditions. 'Abduh's emphasis on internal reform, especially on the reform of education, was appropriated by one of his numerous disciples, 'Abd al-Raḥmān al-Kawākibī (1854–1902).[2]

[1] This research was partially made possible by a fellowship from the Office of Research at the University of Michigan-Flint. I would like to thank the anonymous reviewers for their insightful and constructive criticisms.

[2] Among the works in European languages on al-Kawākibī's life, thought, and influence are: Ronen Raz, 'Interpretations of al-Kawākibī's Thought, 1950–80s', *Middle Eastern Studies*, 32 (January 1996), 179–90; Eliezer Tauber, *The Emergence of the Arab Movements* (London: Frank Cass, 1993), ch. 5; Elie Kedourie, 'The Politics of Political Literature: Kawakibi, Azoury, and Jung' in Elie Kedourie, ed., *Arabic Political Memoires and Other Studies* (London: Frank Cass, 1974); Khaldun S. al-Husri, *Three Reformers: A Study in Modern Arab Political Thought* (Beirut: Khayats, 1966), ch. 4; Norbert Tapiero, *Les Idées réformistes d'al-Kawākibi, 1265–1320=1849–1902: contribution à l'étude de l'Islam moderne* (Paris: Les Éditions Arabes, 1956); Sylvia Haim, 'Blunt and al-Kawākibī', *Oriente Moderno*, 35 (1955), 132–43; and 'Alfieri and al-Kawākibī', *Oriente Moderno*, 34 (1954), 321–34. Among the Arabic works are: Muḥammad Jamāl Ṭaḥḥān, *al-A'māl al-kāmila lil-Kawākibī* (Beirut: Markaz Dirāsāt al-Wiḥda al-'Arabiyya, 1995); and *al-Istibdād wa-Badā'ilahu fī Fikr al-Kawākibī* (Damascus: Ittiḥād al-Kitāb al-'Arabī, 1992); Jān Dāya, *al-Imām al-Kawākibī: Faṣl al-Dīn 'an al-Dawla* (London: Surāqyā lil-Nashr, 1988) and *Ṣaḥāfat al-Kawākibī*, Silsilat Fajr al-Nahḍa, 2 (Beirut: Mu'assasat Fikr, 1984); Muḥammad 'Amāra, *al-A'māl al-Kāmila li-'Abd al-Raḥmān al-Kawākibī* (Beirut: [n.s.], 1975); 'Abbās Maḥmūd al-'Aqqād, *al-Raḥḥāla (Kāf) 'Abd al-Raḥmān al-Kawākibī*

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