

Chapter 1 Calculation and Power: Engagement of Astronomers in Water-Management Projects in the Early Islamicate State

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Abstract

This chapter examines the interplay between mathematical expertise and the socio-political and environmental contexts of the early Abbasid Caliphate. Focusing on Aḥmad al-Farghānī, a ninth-century astronomer renowned for his theoretical work, the study investigates his involvement in civil engineering projects such as the Nilometer in Cairo and a water-supply canal for the newly built city of al-Jaʿfariyya. While his astronomical contributions received high esteem, his practical engineering work was met with disdain, highlighting contrasting views on intellectual versus applied scientific skills. By situating these endeavours within the Abbasid framework, the chapter argues that political ideologies and administrative needs increasingly engaged scientists in water management – a critical factor for Mesopotamian economy and infrastructure. Furthermore, it examines the administrative role of the *al-ḥāsib* (‘calculator’), evaluates archaeological and historical evidence related to al-Farghānī’s canal project, and considers the executive and economic incentives that both drove large-scale water engineering during this transformative period and contributed to its decline. Ultimately, this study aims to enhance comprehension of the political epistemology of the Abbasid era, highlighting how scientific and technological efforts were closely tied to economic objectives and territorial expansion.

Keywords

calculator (*al-ḥāsib*) – water-engineering – al-Farghānī – astronomical computations – Islamicate Renaissance

1 Introduction*

As a response to the political interest of the early Abbasid caliphs during the mid-eighth to mid-ninth century within the Islamicate world, endeavours and resources were dedicated to training scholars who specialised in mathematical techniques, with the goal of enhancing the precision of astrological computations. Following the expansion of the centralised empire and the increasing administrative and economic concerns, these specialists appeared to use their computational skills in a wider range of applications. This paper will closely inspect the mathematical practices of Aḥmad al-Farghānī as an example of a prominent nine-century astronomer dealing with construction activities under the rule of the Abbasids. Being characterised in modern studies largely for his theoretical compositions, his name also appears at the two major engineering projects of his time: The great Nilometer in Cairo, and a water-supply canal for a newly built city, al-Jaʿfariyya. His occupation in civil constructions, however, gave him nothing but dishonour in contrast to the splendour of his scientific writings. This disproportionate amount of success in his scholarly life calls for more attention to the way mathematical skills, executive practices, as well as their interrelations, were perceived during this period. This study seeks to highlight that how examining scientific and technological developments within the broader context of early Islamicate socio-political dynamics enhances our understanding of the way political ideologies influenced scientific endeavours and vice versa. Using textual and non-textual evidence from our case study, we aim to contribute to the study of the political epistemology of the ninth-century Abbasid caliphate by providing insights into the politics of science, its material and ideological dimensions, and the interconnection of political understandings of science and technology with the economic interests and territorial policies of the ruling system.

The involvement of prominent scientists of the time, acknowledged for their computational skills, in water management projects, particularly in the river-dependent life of Mesopotamia, stresses a change in the perception of the relationship between science, society, and environmental resource management. This need appears to have begun two centuries earlier with the rapid growth in settlement, agricultural practices, food production trades, and water distribution projects initiated by Muslim conquerors in the region. The paper

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begins by detailing the concept of “calculator” as an administrative role, covering al-Farghānī’s official position, his expertise in mathematical astronomy along with his involvement in hydraulic plans, and exploring the archaeological evidence and later interpretations of his failure in a caliphal canal-digging project. This discussion is followed by an illustration of the economic context, including the attractiveness and profitability of water-engineering tasks at the time, to emphasise the necessity of integrating studies on scholarly networks and advancements with the decline in large-scale water-supply plans and urban depopulation that began after a period of intensive growth. In the concluding discussion, the paper brings up historiographical viewpoints that underline “Humanism” and “Renaissance” factors in the early Islamicate world alongside territorial, economic, and political developments, aiming to further break down the separation between intellectual history and history of socio-political structures.

2 Who Was a “Calculator”?

The central figure in this paper is Aḥmad b. Muḥammad al-Farghānī, renowned as the author of the *Elements of Astronomy* (*Jawāmi‘ ʿilm al-nujūm* in Arabic), which forms the cornerstone of his reputation. Although his name suggests an origin in central Asia, our knowledge of his life and scientific endeavours is predominantly linked to his association with the Abbasid court in central Mesopotamia. He earned widespread recognition under the title “calculator” (Ar. *al-ḥāsib*), a designation shared by several scholars of his era. However, none of his contemporaries left as substantial a legacy in terms of practical achievements as al-Farghānī did. Some of his civil engineering projects have not only been well-preserved but are also supported by a substantial body of evidence in historical sources. It is by no means, however, coherent and unequivocal information. In the following, I will seek to outline the dynamic relationship between theoretical concepts and practical implementation in the profile of calculators, al-Farghānī in particular, within the context of early Islamicate scientific traditions.

Despite reports on al-Farghānī’s writings and activities, very little is said about the stages of his life and career. The only agreement is situating his flourishing sometime in the first half of the ninth century. No exact date is given on his birth and death¹ and our knowledge about his scientific interests is more in debt to the high popularity of his writings, more specially his compendium

1 A. Ahmedov has speculated that al-Farghānī’s birth date should be roughly in 797–798. An English translation of his Uzbek text can be found in: Abdukhalimov B., “Aḥmad al-Farghānī and His Compendium of Astronomy”, *Journal of Islamic Studies* 10.2 (1999) 142–158, at 143.

of Ptolemy's *Almagest*, cited above.² The highly reputed bibliographer, Ibn al-Nadīm, introduces al-Farghānī as a pioneering astronomer,³ however, a letter he wrote to his patron regarding the Nilometer (Ar. *miqyās*), which serves as a valuable source resembling a project report from a mathematician of that era, has been categorised under the name of an obscure scholar who shares his name. Thanks to modern research, it is now widely accepted that both entries represent al-Farghānī, once as a distinguished astronomer and once as a mathematical practitioner.⁴ In addition to his mastery of mathematics and astronomy as evidenced in the *Elements of Astronomy* as well as his *al-Kāmil* ('The Perfect') on astrolabe,⁵ al-Farghānī's membership in the circle of astronomers at the court of caliph al-Ma'mūn (r. 198–218/813–833),⁶ during whose reign extensive observational projects were carried out, has also been documented.⁷ Since we know that al-Farghānī was alive at least up to 247/861, it is likely that he was a young member of the circle and not a senior one. Al-Bīrūnī, an eminent scientist of a few generations later, relied on his account above others to obtain first-hand information of an observational commission for measuring the terrestrial meridian. The absence of his name among the leaders reinforces the possibility that he was affiliated as a junior fellow to assist and get trained at the same time.⁸

- 2 My doctoral project, which focused on a study of al-Farghānī's *Elements of Astronomy* along with an Arabic edition and English translation of the text, is in progress to be published in the near future. Mousavi R.S., *A Critical Edition, Translation, and Study of al-Farghānī's Elements of Astronomy (c. 860 CE): An Interplay of Meaning and Form at the Intersection of Astronomical and Medical Traditions* (Ph.D. dissertation, Humboldt-Universität zu Berlin: 2023).
- 3 Ibn al-Nadīm, *The Fihrist of al-Nadīm (Abū l-Faraj Muḥammad b. Ishāq)*, ed. A.F. Sayyid (London: 2009) vol. 2, 247.
- 4 See for instance, Ibrāhīm Ī.A., "Muhandis Miqyās al-Nīl. Ma'lūmāt ḡadīda fī dū' al-nuqūš al-kitābiyya li-l-miqyās", *Annales Islamologiques* 39 (2005) 1–8.
- 5 The full title of this book by al-Farghānī is *al-Kāmil ṣan'at al-aṣṭurlāb* ('The Perfect on the Construction of the Astrolabe'). For an edition, English translation, and an instructive introduction of this text, see Lorch R., *Al-Farghānī on the Astrolabe: Arabic Text Edited with Translation and Commentary* (Stuttgart: 2005).
- 6 Every date referring to the Islamic era throughout this paper is presented in a dual format, with both the Hijra and the Common Era indicated, separated by a forward slash.
- 7 Ibn al-Qifṭī, *Ta' rīkh al-ḥukamā'*, ed. J. Lippert (Leipzig: 1903) 78. While Ibn al-Qifṭī differentiates between al-Farghānī the father and al-Farghānī the son, his hypothesis was not favoured by most of the bibliographers after him nor by modern studies. See Sabra A.I., "Al-Farghānī", in Gillispie C.C. (ed.), *Dictionary of Scientific Biography* (New York: 1971) vol. 4, 541–545. On astronomical observations and observatory under al-Ma'mūn's reign, see Sayili A., *The Observatory in Islam and Its Place in the General History of the Observatory* (Ankara: 1988) 50–87.
- 8 Al-Bīrūnī Abū Rayḥān, *The Determination of the Coordinates of Positions for the Correction of Distances between Cities: A Translation from the Arabic of al-Bīrūnī's Kitāb Tahdīd [...]*, trans. J. Ali (Beirut: 1967) 179–180.

Whatever the training program, it indeed proved successful as al-Farghānī wrote at least three well-received texts on mathematical astronomy. The *Elements of Astronomy* which advanced in fame over the others in Arabic, became one of the most recognised astronomical texts in pre-Copernican era thanks to its translations into Latin and Hebrew.⁹ His commentary on the *Astronomical Handbook (Zīj)* by Muḥammad b. Mūsá al-Khwārazmī (fl. c.232/847), the founder of algebra, has not survived, but the large extent of its influence is traceable in later compilations.¹⁰ Al-Farghānī's *al-Kāmil*, according to a study by François Charette, was a ground-breaking work in that it was the first to integrate the required theoretical and practical concepts for constructing an astrolabe in a single book in Arabic.¹¹ To the best of our knowledge, while some Greek texts on projection methods were translated during the same period, it was the first time when the underlying techniques coupled with the methods of application in an Arabic text. Al-Farghānī's ultimate purpose in writing such a work was to defend an account of his patron, Muḥammad b. Mūsá (d. c.259/873), against his chief opponent, al-Kindī (d. c.256/870), the prominent philosopher, who advocated the projection method used for the melon-shaped astrolabe.¹² While al-Kindī is not specifically mentioned in *al-Kāmil*, the account of this disagreement has been passed down through multiple sources. Al-Farghānī provides a general critique of those who create and utilise the astrolabe without taking into account its connection to the physical world and the significance of geometric principles in both its design and operation – a topic I will return to shortly. In fact, the way he recorded and

9 For two informative reviews on Latin translations of the Elements of Astronomy, see Sabra A.I., "Al-Farghānī"; Carmody F., *Arabic Astronomical and Astrological Sciences in Latin Translation: A Critical Bibliography* (Berkeley: 1956) 113–116. On the Hebrew translation, see Shlomo S., "Al-Farghānī on the 48 Ptolemaic Constellations: A Newly Discovered Text in Hebrew Translation", *Aleph* 16.2 (2016) 249–365.

10 E.g., Goldstein B.R., *Ibn al-Muthannā's Commentary on the Astronomical Tables of al-Khwārizmī* (New Haven: 1967).

11 Charette F., *Al-Farghānī's Tables for Constructing Astrolabe: Their Mathematical Structure and Their Importance for the History of Astronomical Instrumentation*, unpublished: paper presented at the conference Ahmad al-Fargani and His Contribution to the Development of World Science (Samarkand and Fergana, October 1998) 1–2. My warm thanks to the author who kindly provided me with a copy of his paper. Cf. Lorch R., *Al-Farghānī on the Astrolabe* 7, who suggests that technical vocabulary in *al-Kāmil* indicates that al-Farghānī wrote his work from the perspective of a mathematician rather than a practitioner.

12 The melon-shaped astrolabe (Ar. *al-aṣṭurlāb al-mubaṭṭakh*) is a special form of astrolabe, based on azimuthal equidistant projection. For further information, see Kennedy E.S. – Kunitzsch P. – Lorch R.P., *The Melon-Shaped Astrolabe in Arabic Astronomy: Texts Edited with Translation and Commentary* (Stuttgart: 1999) 2–12.

discussed this disagreement caused the perpetuation of the debate for generations to come.¹³

In the *Letter* mentioned above, al-Farghānī supplied unique information on the technical and operational aspects of the construction of a new Nilometer in Cairo, a structure used for gauging the Nile River's water levels during annual floods, crucial for calculating land taxes. Al-Farghānī, the executive supervisor of the project, signed the *Letter* with the title “the calculator”.¹⁴ The same name and title were inscribed on the building as the architect, which have survived to the present time.¹⁵ Moreover, in a remarkable amount of the extant manuscripts of his *Elements of Astronomy*, we find his name accompanied by the same title.¹⁶

To my knowledge, there is no exhaustive prosopographical study of these calculators to help us with an insight into their courtly connections and social functioning in the period under study. In regard to al-Farghānī's contemporary colleagues holding the appellation as a calculator, we realise that they had different levels of mathematical skills; while some were high-ranking scientists, judging by their extant works and bibliographical records, some others had no theoretical mathematical activity and only their financial, especially taxational, responsibilities are known to us.¹⁷ What they all have in common,

13 Ibidem, esp. 184–186.

14 This *Letter* has luckily survived through a marginal note on an early manuscript of Ibn Khallakān's *Wafayāt al-a'yān*. For the Arabic text, see Ibn Khallakān, *Wafayāt al-a'yān wa-anbā' abnā' al-zamān*, ed. I. 'Abbās (Beirut: 1970) vol. 3, 112–115. For a French translation of the *Letter*, see Ghaleb Pacha K.O., *Le Mikyās ou nilomètre de l'île de Rodah* (Cairo: 1951) 9–12.

15 For a review on some archeological information of this partly preserved construction, see Ruska J. – Hill D.R., “Mikyās”, in Bearman P.J. et al. (eds.), *Encyclopaedia of Islam, Second Edition* (Published online by Brill: Consulted on 9 July 2024).

16 E.g., Leiden, University of Leiden, MS or. 8481/5, fols. <17>v–<33>r; Moscow, Russian State Library, MS 154/2, fols. <114>v–<199>v. It is, however, curious that Lorch in *Al-Farghānī on the Astrolabe* gives no record of such a title in the surviving copies of *al-Kāmil*.

17 Ḥabash al-Ḥāsib, an astronomer contemporary to al-Farghānī, is a clear example of a senior mathematician, called a calculator. For his scientific contributions, see Charette F., “Ḥabash al-Ḥāsib: Abū Ja'far Aḥmad ibn 'Abd Allāh al-Marwazī”, in Hockey T.A. et al. (eds.), *Biographical Encyclopedia of Astronomers* (New York: 2007). Thomann J. mentions a number of mathematical astronomers from the ninth and tenth centuries in the Islamicate world who were commonly referred to as “calculator” in “From Lyrics by al-Fazārī to Lectures by al-Fārābī: Teaching Astronomy in Baghdad (750–1000 C.E.)”, in Scheiner J. – Janos D. (eds.), *The Place to Go: Contexts of Learning in Baghdad, 750–1000 C.E.* (Berlin: 2014) 503–526, at 514–515. On the other side, Ibn al-Mudabbir can be mentioned as a good example of a top financial manager with the title “calculator”. We have no indication of his mathematical training or attainments. For his biography, see Gottschalk H.L., “Ibn al-Mudabbir”, in Bearman P.J. et al. (eds.), *Encyclopaedia of Islam, Second Edition* (Published online by Brill: Consulted on 9 July 2024). Ibn al-Mudabbir was sent to Cairo on a taxation mission almost at the same time as al-Farghānī. This led William Popper to claim that he was the calculator in charge of the Nilometer and the author of the *Letter*. Popper W., *The Cairo Nilometer. Studies in Ibn Taghrī Birdī's Chronichles of Egypt*, vol. I (Berkeley and Los Angeles: 1951) 22–24. On the significance of arithmetic knowledge among court secretaries in the Islamicate world even prior to this time, see Brentjes S., “Arithmetic”, in Fleet K. et al. (eds.), *Encyclopaedia of Islam, Third Edition* (Published online by Brill: Consulted on 9 July 2024).

as the literal meaning of the title reveals, seems to be dealing with *computation* in various ways. The origin of this managerial position is not known, but the most convincing explanation is that it has its roots in Indian mathematical astronomy in which a group of reckoners, known as *gaṇaka* (lit. calculator) were commissioned to perform astronomical/astrological calculations.¹⁸ Indian astronomy was passed on to court scholars through a senior Indian delegation during the reign of al-Manṣūr (r. 136–158/754–775), best known as the true founder of the Abbasid caliphate, who was also famous for his strong interest in astrological predictions.¹⁹

This scientific collaboration worked so rapidly that in the same generation not only several Indian sources were translated into Arabic, but also Arabic texts based on Indian astronomy were produced by al-Manṣūr’s scientists.²⁰ Taro Mimura has shown that astronomical calculations at that time, when Greek astronomy had not taken over the market yet, were strongly focused on precision.²¹ The virtue of accurate reckoning in astronomical practices was esteemed to such a degree that astronomers recruited and educated their own children and young slaves (“ghulāms”) to assist them in observational projects including computational operations.²²

There is a unique narrative that helps us better realise the high degree of calculation skills for astrological practices in a courtly conversation. At a crowded banquet hosted by al-Ma’ mūn, Yaḥyā b. Aktham, one of the grand judges, began

18 Plofker K., *Mathematics in India* (Princeton: 2009) 178–181, cited also in Thomann, “From Lyrics” 514.

19 Gutas D., *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early ‘Abbāsīd Society (2nd–4th/8th–10th c.)* (London: 2012) 45–52.

20 For the surviving contributions of one of the most prominent astronomers at al-Manṣūr’s court, see Pingree D., “The Fragments of the Works of al-Fazārī”, *Journal of Near Eastern Studies* 29 (1970) 103–123.

21 Mimura T., “Evolution of Geometrical Proofs in Zījēs: Interaction between Calculation and Geometry”, in *Proceedings for the Conference ‘Mathematical Practices in relation to the Astral Sciences’* (unpublished). I am grateful to the author for sending me a copy of his in-press paper.

22 Idem, “Ghulāms (Slave Boys) and Scientific Research in the Abbasid Period: The Example of the Amajur Family”, *Historia Scientiarum* 29.2 (2020) 182–197, esp. 186–190.

to praise the caliph's knowledge by equating him with the legends in various subjects. What is interesting for us is when the judge addressing al-Ma'mūn says: 'concerning astrology, you are like Hermes in his calculations'.²³ Despite his fame and ubiquity in early Islamicate time, Hermes was an unidentified heroic, legendary character. The famous astrologer, Abū Ma'shar (d. 272/886), in an effort to personalise him, introduced three different figures,²⁴ the second of which was thought to train Pythagoras (ca. 570–495 BCE), the admired Greek numerologist. This statement should not be considered as the viewpoint of a distant valuation of calculation skills. Yaḥyā b. Aktham was appointed by al-Ma'mūn to control the resulted numbers of the two groups assigned to a geodetic observation.²⁵ Associating astrological calculations with the Hermetic myth suggests the great standing of astrology as well as computational means to operate it. At the same time, the turn of imperial policy under al-Ma'mūn's reign in favour of Greek teachings left its mark also on mathematical sciences.²⁶ Following the increase in received materials from different cultures, and as a result, the emergence of their disagreements despite many commonalities, al-Ma'mūn called for comparison, verification, and selection between different astronomical disciplines.²⁷ This effort led to a synthesis of Greek geometrical approach to Indian computational techniques that is recognisable in theoretical astronomy,²⁸ however, its implications for applied fields remains to be studied.

23 For the Arabic text, see Ibn Ṭayfūr, *Kitāb Baghdād*, ed. 'I. al-Ḥusaynī (Cairo: 2002) vol. 1, 36.

24 This account by Abū Ma'shar is extant in *Kitāb Ṭabaqāt al-aṭibbā' wa-l-ḥukamā'* (The Classes of the Physicians and Philosophers) by Ibn Juljul (d. ca. d. 384/994). For the text in Arabic, accompanied by a study and English translation, see Van Bladel K., *The Arabic Hermes: From Pagan Sage to Prophet of Science* (Oxford: 2009) 122–129, esp. 124.

25 This project was aimed at measuring the length of one degree on the terrestrial meridian. David A. King, who has scrutinised Yaḥyā b. Aktham's account of this commission in relation to other reports, underscored that despite the meticulous supervision al-Ma'mūn had intended, the numerical data passed down to subsequent generations was notably disorganised. King D.A., "Too Many Cooks ... A New Account of the Earliest Geodetic Measurements", *Suḥayl* 1 (2000) 207–241.

26 As Gutas has extensively discussed in *Greek Thought, Arabic Culture* 83–95, al-Ma'mūn had an anti-Byzantine policy which led him to consider himself as the true heir of the ancient Greek sages.

27 This scientific milestone has well been related by Ḥabash al-Ḥāsib, as a prominent astronomer of the time. For an Arabic text accompanied by English and Turkish translations, see Sayili A., "The Introductory Section of Ḥabash's Astronomical Tables known as the 'Damascene' Zīj", *Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi* 13 (1955) 133–151.

28 Mimura in "Evolution of Geometrical Proofs" argues that the endeavor to provide geometrical reasonings for the calculation instructions found in astronomical tables during this era ultimately gave rise to a fresh approach in the composition of *zīj*es.

In mathematics, al-Ma'mūn's practical concern is interestingly documented in the groundbreaking treatise on algebra by al-Khwārazmī, who was also called a calculator.²⁹ In the introduction, he cites al-Ma'mūn's encouragement for producing a work on the use of algebra in public services as his motivation. Although this text is often mentioned in the scholarship,³⁰ it is beneficial to quote it here too:

(Al-Ma'mūn) encouraged me to write a concise book on algebra enclosing the subtle and major parts of its calculations, for what people frequently need in matters of inheritance, wills, business partnerships, adjudications, commercial deals, and in everything else they need in their interactions including land surveying, canal digging, geometry (engineering), and other similar ways and arts.³¹

This text, among other things, suggests that a mathematician identifies himself as a highly positioned manager of people's daily affairs. The direct users of al-Khwārazmī's technical work could definitely not be the common people, but intermediaries who were supposed to apply this summarised, structured knowledge to people's issues.³²

In addition to the middle class, individuals engaged in various scientific fields also made use of computational works. Physicians, as a major group, needed mathematical astronomers to calculate the climatic divisions, determining daily and seasonal times according to different latitudes, and calendar reckonings that were supposed to help them diagnose and treat diseases. In an account by al-Ruhāwī, a ninth-century physician who wrote a treatise on medical ethics, the support of these experts for medicine has been cherished like a talent for occult sciences:

29 For a historical source from the same era that refers to al-Khwārazmī by this title, see al-Balādhurī Aḥmad b. Yaḥyá, *Jumal min kitāb ansāb al-ashrāf*, eds. S. Zakkār – R. Ziriklī (Beirut: 1996) vol. 4, 274.

30 For two instances, see Gutas, *Greek Thought, Arabic Culture* 133; Charette F. – Schmidl P.G., "Al-Khwārizmī and Practical Astronomy in Ninth-Century Baghdad, the Earliest Extant Corpus of Texts in Arabic on the Astrolabe and Other Portable Instruments", *Sciamvs* 5 (2004) 101–198, at 102. Note that in this paper all translations from Arabic sources are mine, unless otherwise stated.

31 For the Arabic text, see al-Khwārazmī Muḥammad b. Mūsá, *Kitāb al-Mukhtaṣar fī al-jabr wa-l-muqābala: The Algebra of Mohammed ben Musa*, ed. and trans. F. Rosen (London: 1830) 2.

32 For an overview of al-Khwārazmī's mathematical, astronomical, and geographical attainments, see Berggren J.L., *Episodes in the Mathematics of Medieval Islam*, second ed. (New York: 2016) 8–10.

God, the Almighty, has made some matters visible and others hidden, with the purpose of achieving, through subtle rational techniques and the refinement of minds, the transition from the visible phenomena to the knowledge of esoteric ones, much like the endeavors of mathematicians ... From there, they (mathematicians) advanced to grasp the dimensions of various climes, and the overall surface area of the Earth, and then the celestial orbs. Subsequently, they extended their understanding to encompass the precise positions, motions, and distances of the stars, all meticulously arranged for observational purposes.³³

The computational needs of physicians went even further. Qusṭā b. Lūqā (ca. 204–299/820–912), a translator from Greek of Christian origin, explains at the beginning of his book on the science of weights that he wrote it at the request of a patron interested in medicine who sought principles for converting the scales mentioned in Greek texts to the scales used at the time. Qusṭā goes on to say that because the patron is a knowledge-loving person, he is encouraged to develop his composition in a way that serves other arts as well.³⁴

In conclusion, it appears that during the ninth century, the use of calculation as a central part of mathematical sciences was increasingly recognised and applied in administrative as well as scientific activities, thereby earning it a distinct credit. This social perception might have played an important role in the dissemination and establishment of the “calculator”, as an acknowledged occupation title, that was not reserved only for mathematicians. In the meantime, new avenues were opened for astronomers, a group who had undergone intensive training to perform accurate astrological calculations following an earlier ideology of the empire, and to enjoy their computational skill as a career advantage. The question now pertains to the specific domains and methods through which the expertise of an astronomer-calculator could be of assistance.

33 Al-Ruhāwī Ishāq b. ‘Alī, *Adab al-ṭabīb / The Conduct of the Physician*, facs. ed. F. Sezgin (Frankfurt: 1985) 203.

34 Qusṭā b. Lūqā, *Kitāb Fī l-awzān wa-l-akyāl* (‘Book On Weights and Measures’), Istanbul, Ayasofya, MS 3711 (fols. <68>r–<74>v) at <68>r. For an informative study on the knowledge of the weights and balance during the ninth century, with a particular emphasis on Thābit b. Qurra’s contributions, see Brentjes B. – Renn J., “Contexts and Content of Thābit ibn Qurra’s (Died 288/901) Construction of Knowledge on the Balance”, in Brentjes S. – Renn J. (eds.), *Globalization of Knowledge in the Post-Antique Mediterranean, 700–1500* (New York: 2016).

3 al-Farghānī, from an Astronomer to an Engineer

In order to gain a more comprehensive understanding of how practice and theory intersect in the professional experiences of a calculator and former astronomer like al-Farghānī, we should expand our investigation beyond his scientific treatises and encompass primary and secondary sources, along with his involvement in engineering projects. Although al-Farghānī's name is recorded at the two water-related projects, i.e., the Cairo's Nilometer and a canal fed by the Tigris River, he is likely to have been involved in more missions. He was employed by an engineering circle led by Muḥammad b. Mūsá, mentioned above, and his two erudite brothers, Aḥmad and al-Ḥasan, who together were known as the sons of Mūsá. Not only did they have prominent political and administrative positions, but they also excelled in supporting translation of scientific works into Arabic, composing technical texts, and inventing mechanical devices, which are said to have highly impressed the caliph al-Mutawakkil (r. 233–247/847–861), al-Ma'mūn's third successor.³⁵ The former trusted in their skills to such an extent that commissioned the elder brother and the engineers at his service to determine the best place for erecting his new capital city.³⁶ This caliphal concern is in stark contrast to what we are said about the earlier Abbasid caliph, al-Manṣūr, who assigned the key role to the astrologers for specifying an auspicious time for the establishment of his capital, Baghdad.³⁷ The elder brother, Muḥammad, actively engaged in politics and demonstrated his prominent role. He even applied his computational skill to estimate the number of soldiers and livestock in the opposing group during a military crisis, aiding the caliphate in devising effective strategic plans.³⁸

The geographical scope of the activities of these three brothers, according to the Abbasids' centralised rule, was beyond the caliph's headquarters; in addition to the Nile gauge in Egypt, they are also credited with supervising a water structure in Basra, in southern Iraq.³⁹ Although we have not received the name of any engineer in charge for this project, the fact that al-Farghānī's examples in his book on astrolabe were made for latitude 30°, which matches

35 Ibn al-Dāya, *Kitāb al-Mukāfa`a wa-ḥusn al-`uqbá*, ed. 'A. 'Umar (Cairo: 2001) 102.

36 Al-Ya'qūbī Aḥmad b. Ishāq, *al-Buldān*, ed. M. Ḍanāwī (Beirut: 2002) 67.

37 Al-Bīrūnī Abū Rayḥān, *Chronologie orientalischer Völker (al-Āthār al-bāqiyya 'an qurūn al-khālīyya)*, ed. C.E. Sachau (Leipzig: 1923) 270–271; Pingree, "The Fragments" 104.

38 Al-Ṭabarī Abū Ja'far Muḥammad b. Ja'fir, *Ta'rīkh al-umam wa-l-mulūk (Ta'rīkh al-Ṭabarī)*, ed. M. Ibrāhīm, 11 vols. (Beirut: n. d.) vol. 9, 292.

39 Ibidem, 413. This historical account records that the water structure near Basra was 'a canal known as the pillar of the astronomer's sons'.

Basra's location, suggests that he may have also served as an executive engineer for this project.⁴⁰

We do not know how and on what merits al-Farghānī was hired by the sons of Mūsá, but the process of recruiting another key figure of their circle, Thābit b. Qurra (211–288/826–901), a prolific scientist and translator, has survived in bibliographical sources. It is reported that Muḥammad b. Mūsá was so eager to find a worthy candidate to help him in translating Greek sciences that when he met Thābit, a multilingual money-changer, on his return journey from Byzantium (Ar. *rūm*), immediately employed him and took him to Baghdad. The narrative goes on to add that since Thābit was in need of scientific education, Muḥammad funded and trained him for several years in his own household.⁴¹ This account suggests that Thābit's eligibility for such a long-term investment should be twofold: his language skills as well as his calculating talent. These two gifts are also evident in the surviving works of al-Farghānī. Although he was not a translator, he wrote in a very expressive language. In his introduction to *al-Kāmil*, he stresses his goal to reach people with a middle knowledge of astrolabe,⁴² while he has not skipped complex technical aspects. These two proficiencies together, can be interpreted as required intermediary tools for those with advanced knowledge to interact with the administrative middle class.

As mentioned earlier, another stated goal by al-Farghānī in *al-Kāmil* on astrolabe was to demonstrate the falsity of those scientific views, which in his word, were based on *suspicion* and *fantasy*.⁴³ He elucidates this purpose in the introduction as below:

That is why I have authored an all-inclusive book in which I clarify the veracity of the ancients' practices regarding the configuration of the astrolabe, the reason behind it, its true meaning, determining the sizes

40 According to al-Ṭabarī's report (see no. 38), the canal was outside Basra, probably to its south. It may explain one degree difference between al-Farghānī's number and 31 °, the latitude often recorded for Basra in Islamic sources. Kennedy E.S. – Kennedy M.H., *Geographical Coordinates of Localities from Islamic Sources* (Frankfurt am Main: 1987) 71–72. Based on al-Bīrūnī's description of a cylindrical structure from two centuries later in his *al-Āthār al-bāqīya* 264–265, it appears likely that this canal-pillar complex was employed for the purpose of controlling river overflow. For a recent study on al-Bīrūnī's hydraulic and hydrological perspectives, see Borroni M. – Boselli V., "Hydraulics and Hydrology in a Passage of the *Kitāb al-Āthār al-bāqīya* by al-Bīrūnī", *Arabic Sciences and Philosophy* 31 (2021) 159–182.

41 Ibn al-Nadīm, *The Fihrist* 2/1 227–228.

42 Lorch, *Al-Farghānī on the Astrolabe* 24.

43 Ar. *ẓannan wa-takhayyulan* (see *ibidem*).

of all the circles that reflect the sphere of the Universe on the astrolabe, the description of drawing them on it for all areas of the Earth, as well as the invalidation of everything that contradicts the format adhered to by the ancients.⁴⁴

The quotation above suggests that al-Farghānī was focused on emphasising the connection between the theoretical and practical aspects of astrolabic mathematics, all in pursuit of what he calls *the true meaning*.⁴⁵ This particular attention to functionalism is manifested again when he adds the following explanation at the outset of his table of the azimuths to inform the user, who wish to draw lines on an astrolabe plate accordingly, that his computational accuracy is set to the required level for operation, even a little beyond indeed:

In all of the tabulated data, we confine ourselves to degrees and minutes; because in the application of an astrolabe, what is not perceptible or perceivable, including minutes, let alone seconds and beyond, is not needed, even if the astrolabe is sumptuous (*tāmm*) and as large as possible to make.⁴⁶

Likewise, al-Farghānī's attempt in rounding numbers, as convincingly demonstrated by François Charette, marks his commitment to practical concerns, although numbers seem to be rounded up or down only by personal preference without following a systematic procedure. Charette also maintains that the inconsistent level of precision in al-Farghānī's tables may indicate the involvement of some calculating assistants in his work.⁴⁷

It turns out from his star catalogue that al-Farghānī wrote *al-Kāmil* in 244/856, that is, in the last years of al-Mutawakkil's reign. Distinct from his predecessors, the latter had a great appetite for construction projects. He ordered the building of several stunning structures, including the great Mosque in Samarra, which served as the capital of the Abbasid empire during that period. He also sought to exert more control over military groups that had been recruited and empowered during the reign of his forerunners.⁴⁸

44 Arabic text with an English translation in Lorch, *Al-Farghānī on the Astrolabe* 24–25.

45 Ar. *ḥaqīqat dalālatiha*.

46 Lorch, *Al-Farghānī on the Astrolabe* 114.

47 Charette, *Al-Farghānī's Tables for Constructing Astrolabe* 5–8.

48 On al-Mutawakkil and his policies, see Kennedy H., "al-Mutawakkil 'Alā 'llāh", in P.J. Bearman, et al. (eds.), *Encyclopaedia of Islam, Second Edition* (Published online by Brill: Consulted on 9 July 2024). On some of al-Mutawakkil's construction projects, see Northedge A., *The Historical Topography of Samarra* (London: 2007) 195–208, 211–224.

All of this highlights the critical significance of economic considerations. An account that has been unnoticed so far indicates that al-Farghānī held a position of trust as one of al-Mutawakkil's advisors in water supply affairs. In Ibn al-Faqīh's *Kitāb al-Buldān* ('*Treatise of Lands*'), a key source written around the same time, a direct quotation attributed to al-Farghānī informs us that he and his unknown colleagues were questioned by al-Mutawakkil to manipulate the ramifications of Tigris River to increase inflow of water to Baghdad. Their argument in dissuading the caliph, though in non-technical words of a historian, reflects al-Farghānī's long experience in water management, possibly from al-Ma'mūn's time when he was also trained in mathematical astronomy. It is worth reading Ibn al-Faqīh's complete report on al-Farghānī's explanation:

Aḥmad b. Muḥammad [al-Farghānī], the calculator, said: al-Mutawakkil ordered to ease the Tigris channels from Mosul to Baghdad, and to dig out the rocks on their ways. It was said to him: 'O Commander of the Believers! Your uncle, al-Ma'mūn, ordered the same as you did; he was told that God, the Mighty and Sublime, has created these rocks and placed them in these positions. If there is some inconvenience for those whom it passes by, it is in the interest of His servants and the development of His lands for their livelihood. For it repels the water overflows from the two edges of the Tigris, which deserves thanksgiving. It is also necessary for water to join and not disperse and be conveyed over rivers. Were it not for these rocks, the Tigris water would have gone poor until becoming a straight line, and people would suffer as a result, and the lands would be destroyed'. So, he held back from what he initially intended to do.⁴⁹

This witness, despite its value, gives no detailed information on the role of mathematical knowledge in controlling river floods as a major concern expressed here. We have also received no related works in this field from the ninth century scholars, nor we even have enough indications to believe that such skills were circulated in writings. But advanced knowledge in the *Extraction of Hidden Waters* composed by the tenth-century mathematician and engineer, Muḥammad al-Karājī, who was also known as a calculator, as well as al-Bīrūnī's hydrological accounts at around the same period in his *Chronology of Ancient Nations*, suggest that their acquaintance with the

49 Ibn al-Faqīh, *Kitāb al-Buldān*, ed. Y. al-Hādī (Beirut: 1996) 365.

construction and use of mathematical tools for water management must have started from previous generations.⁵⁰

Another calculation-related challenge in al-Farghānī's time, was controlling various calendar systems used in the vast caliphate. This was vital to the imperial economy because of its connection to the determination of fiscal year and agricultural tax policies. Moreover, the religious calendar was lunar and as such did not keep with yearly solar revolutions. Therefore, it was crucial to create a harmony between local calendars, religious feasts, and seasonal cycles. This issue had been recognised and discussed before al-Mutawakkil, however, due to religious considerations any action was avoided. Al-Mutawakkil's decision to reform the administrative calendar was a significant advancement, yet his assassination prevented its implementation during his lifetime. Following a period of succession challenges, this reform was eventually enacted under the rule of Caliph al-Mu'taḍid (r. 279–289/892–902), introducing the insertion of a leap day every four years to the Persian solar calendar. This adjustment aimed to synchronise the traditional agricultural feasts with the shifting seasons, thereby simplifying the organisation of tax collection. These calendrical concerns are also evident in al-Farghānī's *Elements of Astronomy*.⁵¹ In the opening chapter, he presents four distinct calendars from his era (Arabic, Syriac, Byzantine, and Coptic) and offers practical instructions on converting them into the Persian solar calendar.

It is worth noting that calendar maintenance and monitoring seasonal phenomena held a twofold significance for al-Farghānī and his colleagues as water engineers. As judged by Sanad b. 'Alī, an astronomer and rival of al-Farghānī, the failure of the latter's water-canal in al-Mutawakkil's new city, al-Ja'fariyya, was due to its mismatch with the amount of seasonal rainfall. The caliph's desire for construction projects extended to his plan to establish a new city named after him. Al-Ja'fariyya was located eighteen kilometres from the temporary court capital, Samarra, and was aimed at being equipped by an urban water-canal diverted from the river Tigris in its vicinity. The idea was taking a ramification from the river at top of a high hill and directing the water to run through the city. According to Sanad's evaluation as a specialist, which is

50 On al-Karājī's hydrology, see Niazi K., "Karājī's Discourse on Hydrology", *Oriens* 44.1/2 (2016) 44–68; Ataie-Ashtiani B. – Simmons C.T., "The millennium-old Hydrogeology Textbook *the Extraction of Hidden Waters* by the Persian Mathematician and Engineer Abubakr Mohammad Karaji (953 CE–1029 CE)", *Hydrology and Earth System Sciences* 24. 2 (2020) 761–769.

51 Mousavi R.S. – Niehoff-Panagiotidis J., "Harmonization of Calendars in the Early Islamic World as Reflected in al-Farghānī's *Elements of Astronomy*", *Antigüedad y Cristianismo* 38 (2021) 203–209.

repeated also by Ibn Abī Uṣaybi‘a, a thirteen-century historian,⁵² al-Farghānī’s lack of skill in regulating the depth of the canal’s mouth with the fluvial regimes of the Tigris impoverished the canal flow in low rainy months of the year.

Another judgment has been made by al-Ya‘qūbī, a contemporary historian who authored the most extensive text on the geopolitical dynamics of caliphal capitals in the ninth century. Al-Ya‘qūbī blames the rocky ground of the canal for the difficulty of digging and, as a result, the problem of levelling the waterway.⁵³ Archaeological evidence of the city’s remnants, which are well preserved due to its rapid evacuation after al-Mutawakkil’s murder shortly after the canal crisis, supports al-Ya‘qūbī’s report. Excavations have revealed the existence of two humps in the canal path which confirms his explanation about the stony and uneven bed; an issue that could have arisen from hydrogeological incompetence in choosing the right place for the canal.⁵⁴ The former narrative by Sanad, though corrupted by career jealousy, is also of historical value in that it enhances our knowledge about scholarly validation of the connection between civil engineering and calendar calculations during al-Farghānī’s lifetime.

This connection is even more pronounced when considering the Nilometer. The Nilometer consists of a column designed to measure water levels, which fluctuate periodically due to seasonal rainfalls. This scale served not only in preparation for droughts or floods, but also in determining agricultural product taxes. The knowledge associated with this gauge, directly impacting the lives of Egyptians, was considered a closely guarded state secret.⁵⁵ Prior to al-Mutawakkil’s order to build a new Nilometer, referred to as the Great Nilometer (Ar. *al-miqyās al-kabīr*), the oversight and management of regulations for the Nilometer were under the purview of Coptic Christians.⁵⁶ In al-Farghānī’s surviving *Letter* to his patron, he also elaborates on how he graduated the interior walls of the Nilometer. The *Letter* reveals that al-Farghānī’s role as a calculator in this project extended beyond setting measurement standards. He carefully selected verses from the Qur’an that were thematically

52 Ibn Abī Uṣaybi‘a, *A Literary History of Medicine: The ‘Uyūn al-anbā’ fī tabaqāt al-aṭibbā’ of Ibn Abī Uṣaybi‘ah*, eds. E. Savage-Smith – S. Swain – G.J. van Gelder, 5 vols. (Leiden: 2020) 10.1.7. Consulted online on 9 July 2024.

53 Al-Ya‘qūbī, *al-Buldān* 68.

54 Sūsa A., *Rayy Sāmarrā’ fī ‘Ahd al-Khilāfat al-‘Abbāsiyya (Samarra Irrigation during the Abbasid Caliphate)*, 2 vols. (Baghdad: 1948–1949) vol. 2, 348–352.

55 Ruska – Hill, “Miqyās”.

56 Al-Kindī Muḥammad b. Yūsuf, *Kitāb al-Wulāt wa-kitāb al-quḍāt (The Governors and Judges of Egypt)*, ed. R. Guest (Leiden – London: 1912) 507–508.

to survive the dust of history, despite the large number of possible correspondences on similar subjects that have not reached us.

4 Hydraulic Engineering and the Political Economy of the Caliphate

In the early two centuries following the Muslim conquests, several large cities were founded and rapidly expanded in Mesopotamia, playing a crucial role in the formation of Islamicate governance. Many inhabitants of these newly settled areas were former soldiers, and the provision of their food was the responsibility of the state.⁵⁸ During this period, cultivation of lands increased significantly. Given that many of these new cities were chosen in different locations from previous urban settlements, it appears that the Islamicate society followed new environmental considerations.⁵⁹ As studies have shown, the early caliphate's economy revolved around the distribution of lands among families and supporters, conditioned on cultivation and ensuring food supply to the growing population, and paying taxes, although at a lower rate. This reciprocal approach, based on loyalty, can be seen as a form of private entrepreneurship that encouraged landowners to invest in their lands as profitable projects while benefiting the state at large.⁶⁰

The Mesopotamian region's agricultural success relied heavily on river-based irrigation through carefully engineered canals with suitable gradients and knowledge of seasonal floods. Continuous reclamation practices, including drainage, making of new canals, and maintenance of existing ones to exclude surface salts and cultivate fertile lands, were essential. While these agricultural activities brought substantial profits to both the state and landholders, they were also costly and labour-intensive. Therefore, implementing proper land reclamation and irrigation operations had significant economic importance. Moreover, the region's rivers served as vital transportation routes

58 Kennedy H., "The Feeding of the Five Hundred Thousand: Cities and Agriculture in Early Islamic Mesopotamia", *Iraq* 73 (2011) 177–199.

59 One possible reason might be flood prevention, considering earlier catastrophes in the region. See Brown P.J., "Supplying a Medieval Metropolis: Water Management and Agriculture in the Hinterland of Early Islamic Basra", *Water History* 14.3 (2022) 379–398, at 381.

60 For a discussion on whether these activities can be better understood under the rubrics of "state" or "private" projects, with enough care about contextual differences, see Verkinderen P., "Land Reclamation and Irrigation Programs in Early Islamic Southern Mesopotamia: Self-Enrichment vs. State Control", in Delattre A. – Legendre M. – Sijpesteijn P. (eds.), *Authority and Control in the Countryside: From Antiquity to Islam in the Mediterranean and Near East (Sixth–Tenth Century)* (Leiden – Boston: 2019) 500–527, at 520–522.

for goods and people and powered watermills, all under the monopoly of the ruling system.⁶¹ The importation of many slaves for forced tasks such as canal cleaning and desilting led to several crucial revolts due to the hardship of the work.⁶² It seems that the Islamicate state's experience demonstrated by the time of al-Farghānī that labour management on farms was also politically important.⁶³

In *Kitāb al-Ḥiyal* ('The Book of Ingenious Devices') by the sons of Mūsá, a collection of mechanical designs, many of which operated based on pneumatic and hydraulic principles, there are large water dispensers implying that next to luxurious inventions, there were broader services to attract the landlord-aristocracy class for their water management practices.⁶⁴ They even introduced a device resembling today's mechanical grabs used to find lost objects fell into wells or rivers.⁶⁵ These documented efforts to alleviate man's labour and facilitate water access, though limited and narrow, may reflect a scholarly endeavour to adapt to the prevailing market conditions of the period. Studies have shown that although the caliphate was known as a guardian of Islamic legal rules, its economy remained market-friendly.⁶⁶ The caliph's occasional manipulation of laws and fiscal incentives for land investors, along with agricultural-friendly outlook of many jurisprudential opinions of that time (interpreted within their own context), strengthen the theory that private

61 For a recent study on watermills, see Tonghini C., "Flour for the Caliph: Watermills in the 'Land behind Mosul'", in Letizia O. – van Berkel M. (eds.), *The Historian of Islam at Work: Essays in Honor of Hugh N. Kennedy* (Leiden – Boston: 2022).

62 For instance, see Kennedy, "The Feeding of the Five Hundred Thousand" 188–189.

63 By examining three large water projects in various cities during the early Abbasid and Tulunid rules, J.M.C. van den Bent, and P.J. Brown highlighted their extreme cost-ineffectiveness. However, by comparing this context with early Medieval Europe, they argue that these structures were primarily designed to demonstrate the political legitimacy of the government, with their functionality being a secondary concern. See, van den Bent J.M.C. – Brown P.J., "Constructing Hydraulic Infrastructure in the Abbasid and Tulunid Capitals: Water Conduits in Baghdad, Samarra, and Cairo between the Eighth and Ninth Centuries", *Al-Masāq: Journal of the Medieval Mediterranean* 37.1 (2025) 126–145.

64 Wiedemann E. – Hausef F., "über Trinkgefäße und Tafelaufsätze nach al-Ġazarī und den Banū Mūsá", *Der Islam* 8 (2009) 55–93. While a portion of the devices presented in the sons of Mūsá's work can be traced back to Greek origins, their overall contributions surpass those of their predecessors, particularly in terms of automated control systems. For an analysis of the political significance and practical functions of drinking vessels at the Abbasid courts, see Zubani A., "Truth or Dare? Ludic Automata in Medieval Islamicate Courts", *Ludica. Annali di storia e civiltà del gioco* 27 (2021) 73–84.

65 Banū Mūsá, *The Book of Ingenious Devices*, trans. and annotated by D.R. Hill (Dordrecht: 1979) 242–243.

66 For a detailed discussion, see this posthumously published article: Bonner M., "In Search of the Early Islamic Economy" *Al-'Uṣūr al-Wuṣṭā* 27 (2019) 1–39, esp. 4–6, 29–30.

investors played a significant role in the economic development of early Islamic centuries.⁶⁷

Considering the scholarly profile of al-Farghānī and his colleagues during this period, further research is needed to define scientific collaborations and developments within this economic setting and the role of technological advances. Moreover, since al-Farghānī's example stands at the beginning of a period of political chaos – partly due to the unsustainability of the Abbasid fiscal system, which was heavily reliant on political stability⁶⁸ – the decrease in investment in water projects around the same time raises questions about the role of the mathematised approach of water engineers in this process. Additionally, if we accept this critical view of the Islamic economy, which argues it is incompatible with long-term partnerships,⁶⁹ it prompts questions about the lessons that can be drawn regarding intellectual collaborations and the success and failure of technological and scientific ideas in this context. Future research should address these questions by investigating more case studies and piecing them together.

5 Concluding Remarks

In this article, an effort was made to align the theoretical and practical works of al-Farghānī, an astronomer-engineer from the ninth century, who was professionally recognised as a calculator (*al-ḥāsib*), to achieve a more thorough grasp of how his scholarly pursuits were influenced by his mathematical abilities. It has been discussed that the centralised Abbasid empire's demand for enhanced administrative control prompted the necessity to standardise

67 Verkinderen, "Land Reclamation" 522–523. To enhance understanding of the link between consumption and production, Helena Kirchner et al. propose adopting an integrated environmental framework that considers the interconnections among plants, animals, soils, and water, moving beyond the traditional emphasis on new crops and irrigation towards a more comprehensive dataset for future research. Kirchner H. – García-Contreras G. – Fenwick C. – Pluskowski A., "Re-thinking the 'Green Revolution' in the Mediterranean world", *Antiquity* 97 (2023) 964–974.

68 Another potential reason for the failure of Abbasids to invest adequately in constructing and maintaining large-scale irrigation structures could be the simultaneous expansion of their army and the pressing need to provide food supplies. For further discussions on the combined challenges faced by the Abbasid caliphate, see Waines D., "The Third Century Internal Crisis of the Abbasids", *Journal of the Economic and Social History of the Orient* 20.3 (1977) 282–306.

69 Kuran T., "The Absence of the Corporation in Islamic Law: Origins and Persistence", *American Journal of Comparative Law* 53 (2005) 785–835.

diverse measures and promote authoritative agents to replace local management. The training of adept astronomers with advanced computational skills, aligned with the caliphate's ideological establishment, enabled the Abbasids to pursue their administrative objectives. The example of al-Farghānī and the significance of his cultural and political profile offer an enlightening case to gain a deeper understanding of the period's resurgence in various aspects of progress within the Islamicate world.

Numerous studies have attempted to draw parallels between European Renaissances and the cultural and intellectual revivals in the Islamicate world during the ninth and tenth centuries. This has led to the term "Renaissance of Islam" gaining traction in scholarly literature. A significant thread of this inquiry originated with Adam Mez's inspiration from Jacob Burckhardt's *Die Kultur der Renaissance in Italien* (1860)⁷⁰ which subsequently paved the way for the seminal work of Joel L. Kraemer, *Humanism in the Renaissance of Islam* (1986).⁷¹ Kraemer's focus rested on the rule of the Buyids in tenth-century Mesopotamia, a period characterised by a distinct openness and scholarly tolerance. This environment was attributed not only to the aspirations of Muslim scholars, primarily philosophers, to restore the splendour of ancient scientific achievements that they regarded as part of their cultural heritage, but also to the minority status of the Buyids. This minority identity, encompassing both ethnicity and religion, enabled marginalised communities to participate in intellectual endeavours and fostered an environment of inclusiveness, albeit of limited duration. Nonetheless, this context was also recognised as an era of diminished political power when compared to the ninth century, characterised by the dominance of a potent and rich caliphate over centralised territories. Kraemer confirmed, in the introduction to the paperback version of his work, that the fundamental principles of individualism, cosmopolitanism, and secularism he identified in the tenth century had already started to emerge in the preceding century. This emergence was fuelled by an attitude of skepticism, subjectivity of values, and developments in literature and rhetoric.⁷²

In a recent study, Wadad Kadi draws comparisons between Islamicate disciplines with a man-centred focus during this era and the humanistic approaches evident in Europe's Renaissance, commonly referred to as

70 An English translation of Burckhardt's book was made by Middlemore S.G.C. under the title *The Civilization of the Renaissance in Italy* in London in 1878. For Mez's book, see Mez A., *Die Renaissance des Islams* (Heidelberg: 1922). It was translated into English by Khuda Bakhsh S. – Margoliouth D.S. under the title *The Renaissance of Islam* in Patna in 1937.

71 Kraemer J.L., *Humanism in the Renaissance of Islam: The Cultural Revival during the Buyid Age*, 2nd revised edition (Leiden: 1992).

72 Ibidem, XXVIII–XXIX.

the *studia humanitatis*, as far as their subject matter and methodology are concerned. Through her examination of Ibn al-Nadīm’s *Kitāb al-Fihrist*, a prominent bibliographical text from the tenth century, she underscores the significant attention given to the human element in the treatment of diverse disciplines, including those with religious themes.⁷³

If we consider these terms in their literal sense, the Islamicate Renaissance and humanism signify a splendid epoch in cosmopolitan cities such as Baghdad and Samarra. These cities possessed the capacity to accommodate centralised administration, military activities, and intellectual institutions. During this time, there was a lifestyle characterised by enjoyment, prestige, worldly pursuits, and observance of hospitality customs, which is extensively mirrored in surviving poetry and *adab* literature from that period.⁷⁴ Whether representing the majority or minority groups, courtly culture and patronage held significant roles in acknowledging, amalgamating, and systematising scholarly expertise during this era.⁷⁵ In response to political and social ambitions, intellectual circles witnessed intermediary groups operating at the borders of scientific and administrative endeavours. Their purpose was to facilitate a more effective service to the aspirations of the court. This fusion of professions recalls the emergence of “scientist-engineers” during the Italian Renaissance, a development that smoothed the interaction between centres of authority and decision-making with workshops and intellectual establishments.⁷⁶

73 Kadi W., “The Humanities through Islamic Eyes: The Beginnings”, in Günther S. (ed.), *Knowledge and Education in Classical Islam: Religious Learning between Continuity and Change*, 2 vols. (Leiden, Brill: 2020) 43–58.

74 For an informative study on the history and formation of the term *adab* and its chief meaning as “good behavior and etiquette”, see Luca Patrizi, “The Metaphor of the Divine Banquet and the Origin of the Notion of *Adab*”, in Günther S. (ed.), *Knowledge and Education in Classical Islam: Religious Learning between Continuity and Change*, 2 vols. (Leiden: 2020) 516–538.

75 A considerable amount of research, primarily in the form of case studies, has been conducted on court culture and patronage within Islamicate societies. For a meticulous overview of these works, with a specific emphasis on the generation and dissemination of knowledge in Islamicate courts, the recent special issue of the *Intellectual History of the Islamicate World* journal, particularly the editor’s introductory piece, is highly recommended. One of the key points highlighted in this collection is the importance of not overly focusing on the religious motivations of these courts, as this can lead to a distorted understanding of court life during the Islamicate period. Mauder C., “The Production and Transmission of Knowledge in Islamicate Courts of the Middle and Early Modern Periods”, *Intellectual History of the Islamicate World* 11.1 (2022) 1–23.

76 This expression has initially been introduced by Jürgen Renn in his examination of Galileo’s intellectual character. See Renn J. (ed.), *Galileo in Context* (Cambridge: 2001). The idea is extensively explored in Valleriani M., *Galileo Engineer* (Dordrecht: 2010) chapter 6.

Another remarkable aspect of the Islamicate Renaissance is its scientific achievements directed towards providing entertainment for the court. This is best exemplified through the sons of Mūsá, patrons of al-Farghānī, who are credited with commissioning various mechanical devices that had the potential to enhance courtly amusement and infuse a sense of technological innovation into everyday life. Within this context of administrative reforms, urban and structural expansions, and a desire to elevate well-being and delight through scientific advancements, the sciences and their practitioners exerted a significant societal influence. This influence is evident in the emergence of a broad calculator profession, which served as a conduit between the realms of literary-theoretical movements, driven by the increasing translations of foreign sciences, and the court's ideals and desires as a primary supporter of scientific pursuits. As underscored in the paper, al-Farghānī applied his calculation skills also to suggest the most suitable verses from the Qur'an, both in terms of meaning and length, to be displayed on the walls of the Nilometer. While this might appear contradictory to the concept of secularism discussed above, it actually reflects how al-Farghānī employed his mathematical knowledge to showcase the harmony and alignment of the divine message with the external world, which rather fosters than limits his scholarly creativities.

The diverse profiles of the calculators affirm that the emphasis on computational skills was not meant to highlight them as the primary role or capability. Rather, it aimed to underscore these skills as a unifying factor in their expertise, bridging theoretical contributions with practical and socio-political demands. This accentuates that the ability to perform intricate, systematic, and extensive astronomical calculations held significant value during that era, extending beyond the scope of astral knowledge.⁷⁷ The practical significance of astronomical calculations stimulated a reciprocal relationship that also impacted the internal dynamics of the field. An examination of al-Farghānī's profile reveals a shift in astronomers' approaches from prioritising maximum accuracy to valuing calibration, akin to an engineering perspective. Within this pragmatic standpoint, calculation methods for casting horoscopes, creating calendars, and developing ephemerides were seen more as mechanical procedures rather than profound scientific pursuits. These calculations were often relegated to early practitioners as laborious and non-innovative tasks.

77 Lorraine Daston offers a compelling examination of the significant role that astronomical "big calculation" played in mechanical approaches to computation, and their connection to economic efforts toward the division of labor between 1750 and 1950, in her article "Calculation and the Division of Labor, 1750–1950", *Bulletin of the German Historical Institute* 62 (2018) 9–30.

The failure of al-Farghānī in accounting for geological features, resulting in water canal problems, might indicate a lack of comprehensive and predictive planning in the agenda of these astronomer-engineers. His failure could be attributed to a flawed interplay between theory and experience in the codification of the field. Additionally, this paper sheds light on the close association between water management during that period and calendar calculations, which sometimes overshadowed the need for other skills. Al-Farghānī's unsuccessful endeavour could have offered valuable lessons to the subsequent generation of state engineers, a subject ripe for exploration in future studies.

What sets this paper distinct in the context of comparing European Renaissances with Islamic intellectual revivals is its focus on the role of mathematics, an aspect often overlooked. While previous studies emphasise the contributions of philosophers, theologians, and literary figures, the involvement of mathematicians offers the advantage of addressing both practical necessities and theoretical considerations. It is worth emphasising that here too, parallels can be drawn to the Italian Renaissance, albeit on different scales. This is evident not only in Galileo Galilei's pursuits but also in the life and career of Giovanni Battista Benedetti, which has been exhaustively investigated in a recent study by Pietro D. Omodeo and Jürgen Renn.⁷⁸ An intriguing resemblance between my study and the latter lies in the shared intention to challenge the boundaries of scholarly thought by rejecting prevailing trends supported by past authorities under the patronage of practice-oriented courts. The clashes involving al-Farghānī and the sons of Mūsá with al-Kindī, a towering philosopher during the reign of the former rulers, paved the way for them to transcend established disciplinary boundaries and explore new domains.

In summary, this paper recognises the connection between knowledge and its contextual and cultural circumstances, as well as its integration into social and political processes, particularly within the court culture. To fully comprehend the delineation of scholarly fields, it is essential to situate individual accomplishments within their social context and cultural interactions. Sticking to this scope, historical case studies can also enhance our comprehension of the sociological foundations of modern science and its political significance, as discussed in seminal works such as Rose and Rose's *Science and Society* (1970) and John Bernal's *The Social Function of Science* (1939), among others.

⁷⁸ Omodeo P.O. – Renn J., *Science in Court Society: Giovan Battista Benedetti's Diversarum speculationum mathematicarum et physicarum liber (Turin, 1585)* (Berlin: 2019).

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