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## Article

# Hybrid Knowledge and the Historiography of Science: Rethinking the History of Astronomy between Second-Century CE Alexandria, Ninth-Century Baghdad, and Fourteenth-Century Constantinople

Alberto Bardi[1] [https://orcid.org/0000.0002-9440-2849]

## Abstract:

Originating in the field of biology, the concept of the hybrid has proved to be influential and effective in historical studies, too. Until now, however, the idea of hybrid knowledge has not been fully explored in the historiography of pre-modern science. This article examines the history of pre-Copernican astronomy and focuses on three case studies—Alexandria in the second century CE; Baghdad in the ninth century; and Constantinople in the fourteenth century—in which hybridization played a crucial role in the development of astronomical knowledge and in philosophical controversies about the status of astronomy and astrology in scholarly and/or institutional settings. By establishing a comparative framework, this analysis of hybrid knowledge highlights different facets of hybridization and shows how processes of hybridization shaped scientific controversies.



**Keywords:** Astronomy; Astrology; Hybrid Knowledge; Alexandria; Baghdad; Constantinople

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## Introduction

Originating in the field of biology, the concept of the hybrid has proved to be influential and effective in historical studies, too (Stross 1999). However, the idea of hybrid knowledge has not been fully explored in the historiography of pre-modern science. This article examines the history of astronomy (and astrology)[2] from late antiquity till the fifteenth century and focuses on three case studies—Alexandria in the second century CE; Baghdad in the ninth century; and Constantinople in the fourteenth century—in which hybridization played a crucial role in the development of astronomical knowledge and philosophical controversies

[1] Alberto Bardi is an Assistant Professor in the Department of the History of Science at Tsinghua University. Address: Department of the History of Science, School of Humanities, Tsinghua University, Haidian District, Beijing 100084, China. E-mail: alberto.bardi@live.com.
[2] From antiquity till early modernity, astrology was not terminologically distinguished from astronomy. Among others (Rutkin 2019). In the current paper, both astronomy and astrology will be under consideration, and I will properly explain the distinctions below, turning to Ptolemy's own statements to do so.

about the status of astronomy and astrology in scholarly and/or institutional settings. My use of "hybrid" and its relatives derives from influential work in intellectual history, such as the notion of hybridization in knowledge as defined by Anna Winterbottom. She uses "hybrid" "to encapsulate what the diverse ways of knowing that I will explore have in common with one another: an admixture of information drawn from diverse sources drawn together to make something new." (Winterbottom 2016, 2).[3] Steven Shapin points out the inevitable hybridity of social and scientific knowledge (Shapin 1994 and 2010). With an awareness of this limit, the study considers Alexandria in the second century, Baghdad in the ninth, and Constantinople in the fourteenth, in order to cover a wide spectrum in the pre-Copernican history of astronomy.[4] These cases offer three radically different historical-intellectual contexts as well as diverse cultural, religious, and institutional settings. Therefore, by putting them into a comparative framework,[5] this analysis of hybrid knowledge will highlight facets of hybridization in several instances, and will show the following: how processes of hybridization are used in intellectual controversies to legitimize or reject "foreign knowledge" (e.g., from Hellenistic to Islamic cultures and from Islamic to Byzantine); how legitimization triggered the creativity of scholars to produce or justify new forms of knowledge; how hybrid knowledge links to clashes between radical religious factions and groups of scholars open to new forms of knowledge in both the Islamic and the Byzantine worlds; and how hybrid knowledge links to the reconceptualization of the epistemology of astronomy and astrology from one culture to another.

## Alexandria in the Second Century CE: The Hybrid Nature of Astrology and the Betrayal of Platonic Ideals



The major product of Hellenistic astronomy is undoubtedly the *Great Mathematical Syntax*, better known as the *Almagest*, of Claudius Ptolemy, a scholar who worked in Alexandria under Roman rule in the second century (Toomer 1984, Pedersen 2011). The work itself can be described as the result of a hybridization of Greek geometry with Babylonian arithmetic.[6] Hybridization, in this case, means not only a successful mixture, but the production of new knowledge,[7] for instance, a new kind of astronomical table (discussed below).

The *Almagest* provided a mathematical astronomy that was useful not only for computing planetary positions and eclipses but also for decision-making, weather forecasting, and making predictions about many other aspects of life and nature, commonly known as "astrology." The latter has been distinguished terminologically from the scholarly tradition of "astronomy" in modern times (Rutkin 2019). Moreover, there have been controversies over astrology's status as a science. Notions of hybridity shed new light on these controversies and their cultural settings.

The most influential systematization of knowledge that can be labeled "astrology" was redacted in the second century in Ptolemy's *Tetrabiblos*, also known as *Apotelesmatics* (Ptolemy 1940). The introduction to the work helps us to understand astrology through the eyes of Ptolemy and the Alexandrian scholars:

[3] Further publications which inspired the current study include: (Burke 2009), (Burke 2016), (Stockhammer 2012).
[4] Copernicus' major work, *On the Revolutions of the Heavenly Spheres*, was published in 1543, but a first draft of his heliocentric theory was written around 1515 and circulated among his peers (see Swerdlow 1973).
[5] For this methodology I am indebted to Ma and Van Brakel (2016).
[6] This claim is often implicit in the historiography of astronomy. For an explicit statement see Anderson (1962: 175).
[7] For a detailed overview of the novelties provided by Ptolemy in the *Almagest* see Goldstein (2007).

> Of the means of prediction through astronomy, o Syrus, two are the most important and valid. One, which is first both in order and in effectiveness, is that whereby we apprehend the aspects of the movements of sun, moon, and stars in relation to each other and to the earth, as they occur from time to time; the second is that in which by means of the physical character of these aspects themselves we investigate the changes which they bring about in that which they surround. The first of these, which has its own science, desirable in itself even though it does not attain the result given by its combination with the second, has been expounded to you as best we could in its own treatise by the method of geometrical proofs. We shall now give an account of the second and less self-sufficient method in a properly philosophical way, so that one whose aim is the truth might never compare its perceptions with the sureness of the first, unvarying science, for he ascribes to it the weakness and unpredictability of material qualities found in individual things, nor yet refrain from such investigation as is within the bounds of possibility, when it is so evident that most events of a general nature draw their causes from the enveloping heavens. But since everything that is hard to attain is easily assailed by the generality of men, and in the case of the two before-mentioned disciplines the allegations against the first could be made only by the blind, while there are specious grounds for those leveled at the second—for its difficulty in parts has made them think it completely incomprehensible, or the difficulty of escaping what is known has disparaged even its object as useless—we shall try to examine briefly the measure of both the possibility and the usefulness of such prognostication before offering detailed instruction on the subject. (Translation Robbins, slightly reworked, see Ptolemy 1940, 2–4)



Briefly, astronomy is endowed with a higher degree of certainty, granted by geometrical proofs, while astrology is a less self-sufficient branch—the physical branch—of astronomy. "Physical" here refers not to physics, as in the modern sense, but to the sublunar world (*physis*). Astrological foundations are based on the grounds of the regular occurrence of the same effects of the sun and the moon, and of other regular occurrences, which were compiled via the observations of not only astronomers, but also farmers and sailors. To elevate these observations to the level of science, accurate knowledge of the movements of the heavenly bodies is necessary. In other words, the observer needs to have studied the mathematical astronomy contained in Ptolemy's *Almagest*. A mathematized form of divination, astrology can be taken as a hybrid form of knowledge that combines mathematical astronomy with divination.

In the *Tetrabiblos*, Ptolemy argues that astrology does not enjoy a good reputation chiefly because of the mistakes of unskilled astrologers and the financial motivations of the people who produce horoscopes. Aside from these factors of social history, astrology's scientific status is intrinsically subject to criticism because: 1) the object of study of astrology lies in the sublunar world, which is *per se* subject to change and instability; 2) the same configuration of the heavens is never exactly repeated—at least, not within the lifetime of a single observer. Therefore, replicability cannot be taken as a criterion for this science and observation plays a minimal role. However, the third chapter of the *Tetrabiblos* stresses the usefulness of astrology. Similar to ancient historiography, it helps predict what is likely to happen in the future, so that people can take preventive measures to avoid harm. Although Ptolemy does not convey the notion that events befall mankind as if they were preordained by divine command, astrology's predictive faculty gave rise to issues that would (and continue to) attract criticism on the grounds of determinism and the role of free will.

Before looking further into astrology, some comments here on the *Almagest* will be expedient. According to Ptolemy, the very goal of mathematical astronomy was to educate

people in order to contemplate the laws governing the heavens and thus become, in the Platonic sense, god-like. For Ptolemy and his fellow scholars, mathematics, not theology, was the highest form of philosophy.[8] The *Almagest* provided its audience with the know-how to construct an innovative kind of astronomical table, which would create a quantitative representation of the geometrical models expounded in the *Almagest* in user-friendly, tabular form. In the *Almagest,* a table never appears on its own, but always as a constitutive element of a complex mathematical argument that relates the tables to the geometric model (Sidoli 2014). The goal of the tables was to show that apparently irregular motions are actually based on the periodic motions of circles. The tables attracted the attention of people uninterested in the theory, such as astrologers. Furthermore, a new mathematical practice of astronomy in tabular form had been inaugurated, and would continue to influence the history of astronomy for centuries thereafter.

After completing the *Almagest*, Ptolemy established a structured set of astronomical tables, known as *Handy Tables*, which were adapted from the tables embedded in that earlier treatise. Ptolemy also produced a short introduction to the *Handy Tables*, disseminated separately from the tables themselves, known as the *Psephophoria* or *Arrangement and Calculation of the Handy Tables* (the title varies considerably in its manuscript forms). The text comprises chapters listing and explaining the use of the individual tables. The tables were of immense importance in antiquity and medieval traditions of the Western and Eastern Mediterranean and the Middle East. They superseded other formats of astronomical knowledge, such as the tables of Babylonian tradition.[9] One may think immediately of Ptolemy's tables when reading that astronomy in the Middle Ages was the "science of kings" and that kings, caliphs, and emperors would pay large sums for the best and most accurate astronomical tables. Someone in full possession of the know-how provided by the astronomical tables would be able to draw schematic maps (horoscopes) of the heavens for the present, past, and future, which could then be properly interpreted after studying the *Tetrabiblos*. The true philosopher, according to Ptolemy, learns both the *Almagest* and *Tetrabiblos*, and in that way, can reach full contemplation and become god-like.



The social history of astronomy registers a significant change after the second century CE. The proofs one was supposed to learn to become a true philosopher were perceived as too difficult. This was likely one of the reasons why Ptolemy reworked the tables and set them into a single work, the above-mentioned *Handy Tables*,[10] and provided instructions on how to use them. Moreover, the Alexandrian commentators of Ptolemy's work, the mathematicians Pappus and Theon,[11] evidence the difficulty of the subject and the problems encountered by students in Alexandria. For instance, in his *Commentary on the Almagest*, Theon describes the situation in fourth-century Alexandria:

> What has been left without a commentary seems difficult. As for those people about whom Ptolemy, at the beginning of the work [i.e. the *Almagest*], says are willing to prove the whole topic geometrically, they end up managing most of the topics in handy tables through simple methods. On the contrary, we have not only put our best efforts into going through each topic through geometrical proofs as far as possible, but have also left nothing at all of difficult teaching, and we are not among those people who hold this opinion on the subject. (My translation; original text in Rome 1931–43, vol. 2, Book 1, p. 318 ll.8–14).

[8] On Ptolemy's philosophical foundations see Boll (1894), Taub (1994), and Feke (2020).
[9] For a study of the different kinds of tables circulating in Roman Alexandria and the novelty of Ptolemaic tables see Jones (1997a, 1997b, 1998, 2000).
[10] The edition (partial) of the Handy Tables is provided by Tihon and Mercier (2011).
[11] On Pappus see Gillispie (1970–1981, vol. 10, 293–304), on Theon see Gillispie (1970–1981, vol. 13, 321–325).

In a similar fashion, Theon's *Little Commentary on the Handy Tables* reports:

> My Epiphanius, we have accurately provided a more rational method for the computation of the stars in the *Handy Tables* in another treatise in five books. However, because the majority of those who followed our classes in order to learn the subject not only are unable to follow sufficiently the multiplications and divisions of the numbers, but also are completely ignorant of geometrical proofs, we have done our best to systematically comment on them [the tables] by providing plain methods so that the exposition of the subject would be clearer to them [i.e. those who do not understand geometry]. (My translation; original text in Tihon 1978, 199, ll. 1–10)

People referred to the tables simply to learn how to use them, without comprehending the geometrical proofs underlying their construction. After the second century, the Hellenistic world increasingly saw scholars adopting the use of tables without education in geometrical proofs, in practice that was likely perceived as "astronomy" and "science" among the educated population. Contrastingly, from Ptolemy and his peers' philosophical perspective, this could constitute a betrayal of Platonic philosophy. The transmission of this betrayal from Alexandria to Baghdad and to Constantinople offers new insight with which hybrid astronomical knowledge in the Arabic and the Byzantine worlds can be examined.

## Ninth-Century Baghdad: Abū Maʿšar and the Criticism of Astrology

Ptolemaic works reached the Arabic world through translations from Syriac and Middle Persian. The elements we have found in Ptolemy and his commentators in terms of theory, practice, and difference in the nature of the two branches of astronomy were transmitted almost unchanged. There is evidence of this in ninth-century Baghdad in the work of the renowned pupil of Al-Kindī, Abū Maʿšar. In his *Great Introduction to Astrology*, Book One, Chapter Five sets out ten points of criticism against astrology, which Abū Maʿšar carefully refutes in order to legitimate astrology as a science.[12] Among these criticisms and refutations, the third is especially important for the current study, and it starts as follows:



> The people of reflection and disputation refute the science of astrology, saying that the stars do not indicate a thing which comes to be in this world. They argue this by claiming that the stars do not indicate the possible (contingent). We shall now discuss some arguments of the Ancients who rejected the possible. Then we affirm

[12] Here I cannot treat all points in detail. For the comparative framework of the current study, points 3 to 6 proved to be the most appropriate. The reader will find excellent explanations and discussions of all points in Burnett (2002, esp. 206–211) as well as Burnett and Yamamoto (2019, vol. 1, 12–15), to which I am indebted. The English translation from the original Arabic is Burnett and Yamamoto (2019, vol. 1, 107–150). Since I treat points 3 to 6 below, I offer a brief sketch of the other points in the following. Point 1 refutes the arguments of those who criticize astrology as unfounded on the ground that planets have no influence on anything below the sphere of the Moon; point 2 concerns the argument that the planets indicate universal things, not individuals; point 7 deals with the criticism moved against astrology from people unable to master the theory; point 8 concerns some physicians who, inspired by the promise of making a quick profit, do not want to properly study medicine, which includes astrology; point 9 moves against accusations from people who esteem science on the basis of scientists' income; point 10 refutes those who consider astrology unscientific on the basis of the practice of incompetent astrologers (those who avoid the mathematics).

> the possible. Then it will become clear that the stars indicate the possible. (Translation Burnett; see Burnett and Yamamoto 2019, vol 1, 111)

The rest of the objection addresses accusations of astrology as being deterministic and denying free will. As convincingly shown by Adamson (2002), Abū Maʿšar can be deemed a "compatibilist" because he argued that free will is not denied by the determinism that astrology apparently generates. Briefly, Abū Maʿšar recalls Aristotle and claims that not everything has to be necessary or impossible, but that some things could go either way (in other words, they are contingent). Similarly, the planets, which were endowed with rational souls, indicate the necessary, the impossible, and the contingent. Since both planets and human beings are faced with the necessary, the impossible, and the contingent, the faculty of choice in human beings is not affected by determinism, because a choice evolves from the confrontation of the human rational soul with the human animal soul. The planets, instead, determine the relationship between the two parts of the human soul. On this account, the human being is free to choose what the stars indicate.

Abū Maʿšar's *Great Introduction* also criticizes the fact that both branches of the sciences of the stars were considered problematic in ninth-century Baghdad. For instance, Point Four addresses the opinion shared among astronomers that stars influence only the changes of the seasons. As a refutation, Abū Maʿšar employs Ptolemy's recommendation, mentioned above, that in order to study astrology properly, one must master mathematical astronomy along with its geometrical proofs. Thus, Abū Maʿšar and his followers also took the *Tetrabiblos* and the *Almagest* to be complementary.

Point Five states that astronomers reject astrology on the grounds that no one has the length of experience of observing the stars necessary to verify whether a repeat of the same configuration of the stars brings about the same effects. Abū Maʿšar replies that astrologers, specifically as mathematical astronomers, rely on the collective experience of their predecessors, such that it is valid to make deductions from analogy.



Point Six claims that astrology is unscientific on the grounds that different astronomical tables give different values for the positions of the planets. In this instance, Abū Maʿšar argues that number-counting is not the most important part of astrology. If an astrologer gets the wrong values, the blame should be put on the mathematicians who provided the numbers in the tables. Once again, the mathematics of the *Almagest* is *conditio sine qua non* for the good astrologer.

As for the "people of reflection and disputation" mentioned in Point Three, this can refer to two groups, according to Burnett's and Yamamoto's studies of Arabic manuscripts (Burnett and Yamamoto 2019): *ahl an-naẓar wa-l-ǧadal*, or Mutazilites, according to one manuscript tradition; *ahl al-ḥadīṯ wa-n-naẓar*, or "traditionalists," according to another. The latter rejected astrology on the grounds that it was a foreign science and its Greek philosophical foundations were not in accordance with the teaching of the Qur'an, and were thus potentially harmful to society.[13] The Mutazilites, on the other hand, were in favor of Greek knowledge and translated and disseminated Greek science and philosophy in Arabic. Therefore, they struggled to make the case that astrology was discordant with the foreign sciences they were mastering, and that it was unfounded, employing the points of criticism recalled by Abū Maʿšar. The two groups, alongside other factions (Saliba 2002), were living amid a climate of political struggle for cultural hegemony, and the discrepancies between astrology and the doctrine of the Qur'an therefore played a crucial role in astrology gaining official acceptance.

[13] For a survey on the factions in favor and against astrology in ninth-century Baghdad see Saliba (2002).

At any rate, in Baghdad, astrology was understood, at least by an influential group of scholars, as an integral part of astronomy, as Ptolemy proposed, with the *caveat* that astrologers cannot pretend to foretell the future with certainty, for that is a domain of knowledge that pertains only to divinity. In that cultural context, Abū Maʿšar managed to establish the foundations of astrology by considering it as a part of natural philosophy, conceived of in an Aristotelian framework. Astrology could enjoy the status of a science because it discovered causes by observing effects, and it could be freed from accusations of determinism or of being against the teachings of the Qur'an.

In summary, astrology could be considered hybrid with regard to both its disciplinary status and the traditions from which it stemmed. In ninth-century Baghdad, the hybridity of astrology as a discipline led the Mutazilites to criticize it as an unfounded science, while the hybridity of its cultural origins served as the main target of attack by those advocating the purity of Quranic teaching (discussed further in the Conclusion below).

## Fourteenth-Century Constantinople: The Reception of Abū Maʿšar and Controversies about the Status of Astronomy and Astrology

Abū Maʿšar's *Great Introduction* and *The Nativities* were translated into Greek at a certain point. Surviving manuscripts of the Greek versions of the *Great Introduction* stem from the fourteenth century onwards, according to David Pingree's examinations.[14] The Byzantine world had already inherited all the problems related to the status of astronomy and astrology from the achievements of Alexandrian scholars, benefitting from linguistic and stylistic continuity. As early as the seventh century, the Byzantines had their first handbook on the *Handy Tables* of Ptolemy, ascribed to Stephen of Alexandria working for the emperor Heraclius, and astrological aims were deliberately included, because astrology was cultivated in Byzantine imperial courts (Magdalino and Mavroudi 2007). The Ptolemaic conception of astrology as a less self-sufficient branch of astronomy permeates the centuries of Byzantine culture as well as troubling its status as a science. This is likely the reason why the ten points of criticism of the *Great Introduction* (Book One, Chapter Five) are missing in the extant Greek manuscripts. Astrology was frequently the subject of polemics throughout the Byzantine era. In the fourteenth century, this criticism led to the formation of factions which partially resembled the "traditionalists" and the Mutazilites mentioned by Abū Maʿšar.



Before delving into this scenario further, here it is worth mentioning the brief work *Hermippus On Astrology* (*H. De Astrologia*).[15] The great German philologist Franz Boll discovered that this text contained a portion of Abū Maʿšar's *Nativities* that had been translated into Greek and interpolated (Boll 1912).

At first glance, *Hermippus* shares more similarities with the *Tetrabiblos* than with the Greek version of Abū Maʿšar. This could be due to linguistic continuity, but there are other possible explanations, too. In the extant literature, there is no consensus about the composition and the authorship of *Hermippus*. Manuscript editions of the text date from the fourteenth century but it may have been composed earlier. There are two candidates for the text's authorship: John Catrarios and Nikephoros Gregoras, both of whom were active as scribes and composers of astronomical texts in fourteenth-century Byzantium (Jürss 1964). *Hermippus* has been described in the literature as a dialogue on astrology and a defense of it. I am skeptical about its dialogical nature, because *Hermippus* and his interlocutor have only a few exchanges; it is arguably a monologue of Hermippus. Furthermore, it is more a treatise on the beauty of astrology than a defense against criticism, since it touches on all the

[14] See Burnett and Yamamoto (2019, vol. 2, 1–5).
[15] The Greek text is edited in Kroll and Viereck (1895). I am currently working at the English translation.

possibilities that are granted to those who want to study astrology. The book explains the nature of the planets (which are endowed with souls) and the effects of their conjunctions on the world and human affairs, the nature of the human soul and its parts, and how they influence our decisions. Unlike Abū Maʿšar, Hermippus is not a compatibilist. In fact, his Neoplatonic framework does not generate any concerns about determinism. The author even employs Neoplatonic concepts to describe the nature of Christian concepts, such as the Holy Trinity:

> I will plainly explain what's left, that is: reason (λόγος) is the vehicle of the intellect, the soul is the vehicle of reason, and the spirit is the vehicle of the soul. […] For this reason, when we are successfully and appropriately inspired—if we observe properly—we worship the three hypostases in God and the mystery of the triad [i.e. trinity] from which life begins and was revealed to us. That which is the intellect in us is the father in them [the hypostases], reason is the son, the soul is the [holy] spirit, and by them, the spirit is uncreated and life-generating. (My translation; original text in Kroll and Viereck 1895, 21)

What is also striking is that the author claims astrology is necessary in reaching the contemplation of God, implying that Scriptures, prayers, and ascetic practices alone would not be enough (Magdalino 2006, 154–157). Unlike Ptolemy and Abū Maʿšar, the author does not elaborate on proofs or the use of tables, indicating the introductory character of this work.

Hermippus' statements would have sounded problematic in fourteenth-century Byzantium. In Constantinople, instead of Mutazilites and traditionalists, there were hesychasts and Palamites. Furthermore, there were controversies not just surrounding astrology but also regarding theological issues, such as the procession of the Holy Spirit.[16] The hesychasts, originally a group of monks on Mount Athos, were considered specialists in reaching the contemplation of God through a specific ascetic practice, called "the prayer of the heart." The group became very influential in the Orthodox world in the fourteenth century and was attacked in 1337 by Barlaam the Calabrian, a Byzantine scholar from Italy. He claimed they were mad and that it was impossible that they could see the Uncreated Light of God as a result of the prayer of the heart. An influential Byzantine theologian, Gregory Palamas, defended the group, refuting Barlaam by developing a doctrine to distinguish God's "essence" from God's "activities." According to Palamas, the latter was reachable through ascetic practices like those of the hesychasts, while the essence of God, according to Scriptures, is unknowable to human beings.

In the 1340s and 1350s, the polemics between Barlaam and Palamas became a matter of official theological discussion in the Church of Constantinople. Eventually, Barlaam was condemned as a heretic and converted to Catholicism, while the doctrine of Palamas became official in the decrees of the Council of 1351. *De facto*, without being hesychast and a follower of the doctrine of Palamas, it was hard to be accepted into the scholarly realms of the Church of Constantinople.

The Church of Constantinople had always treated astrology with suspicion, but once the prayer of the heart and the doctrine of Palamas became part of the official sphere, the Church turned completely against the practice of astrology and its epistemological capacity, such as some statements in the *Hermippus*. According to the Byzantinist Paul Magdalino, astrology and ascetic practice became two competing epistemologies which eventually clashed (Magdalino 2006).

[16] On hesychasm and Palamism see, among others, Meyendorff (1974), Rigo (2004). An overview of late Byzantine social, political, and ecclesiastical history is offered by Nicol (2008).

Evidence of this is provided by Theodorus Meliteniotes' rejection of astrology in all its aspects and applications. Meliteniotes was a hesychast, Palamite, and Rector of the Patriarchal School of Constantinople whose treatise on astronomy, composed around 1352, was entitled *Three Books on Astronomy* (Bardi 2020). The first two books deal with the use of the astrolabe and the tables of Ptolemy, while the third is a handbook on Islamic astronomical tables (*zījes*) translated into Greek from the original works by Maraghan astronomers, imported into Constantinople via Trebizond at the beginning of the fourteenth century through a cultural broker—the Byzantine scholar Gregory Chioniades (Pingree 1964; 1985). Chioniades had traveled to Tabriz in the Ilkhanid Empire and learned the science of the stars from experts whom he refers to as "Persians," then came back via Trebizond, where he would have finalized his translations.

While Chioniades' works, as well as those of Meliteniotes, deal with the side of astronomy that does not require one to learn geometrical proofs, in around 1300 the polymath Theodorus Metochites developed the first Byzantine commentary on the *Almagest*, comprising proofs, theorems, and tables (Bydén 2003; Paschos and Simelidis 2017). He followed the conceptual distinction between astronomy and astrology as Ptolemy and Abū Maʿšar had done. However, unlike Ptolemy, he classified astronomy according to an Aristotelian framework, therefore placing theology as the highest form of knowledge, and the study of the stars as a step below. Given the double nature of celestial objects, which fall under the domains of both mathematics and physics (natural philosophy), the study of the abstract properties of those objects was more easily executed due to the certitude granted by mathematical proofs. Metochites accepted astrology as influential in the sublunary world but rejected its possible influence on human decisions on the grounds of determinism and denial of free will, which would lead to a loss of responsibility in the field of human actions. He was not a "compatibilist," but rejected astrology on moral, rather than scientific, grounds. Due to the difficulty of Metochites' prose and his taste for the proofs of the *Almagest*, he was almost an isolated voice, with the exception of his pupil Nikephorus Gregoras, who was keen on mathematics, but whose career was limited by his not being a hesychast. As a result, the Byzantine manuscripts from the fourteenth century contain dozens of copies of astronomical tables from both Ptolemaic and Arabic traditions, but nobody has ever challenged the *Almagest* as scholars did in the Arabic world. Transcriptions and marginal notes indicate that some attention was paid to Ptolemy by Byzantine scholars before Metochites.



Similar to methods used to disparage the traditionalists mentioned by Abū Maʿšar, astrology was tactically labeled a "foreign science" in Constantinople, in order to reject it as an opposition of monotheistic principles. Gregory Chioniades, on account of his encounters with Muslim scholars, had to make a profession of faith in Constantinople to prove his orthodoxy. The use of tables for astrological purposes was not new to Byzantium, but the practice became politically sensitive during the civil wars in late Byzantium and became an essential part of the theological debates concerning the proper way to reach God, as in the case of Barlaam against Palamas.

Meliteniotes' work emblematizes the incorporation of "foreign astronomy" (tables taken from *zījes*) into the Byzantine world. Unlike the translations of Chioniades, Meliteniotes omits astrological chapters in his handbook to the so-called "Persian Tables" (Bardi 2018). However, the content of his *Three Books on Astronomy* is exclusively practical, comprising instructions on how to use the tables of Ptolemy alongside those of the *zījes*. On the one hand, Metochites' treatise on the *Almagest* considers astronomy as a whole and as a means of helping one become god-like through the learning of proofs and theorems. On the other hand, Meliteniotes' approach marks a radical rejection of the double nature of astronomy, banning astrology from the program of the Patriarchal School of Constantinople, where he was working as rector around 1352. In other words, in late Byzantium there was no consensus on the concept of a "true philosopher" as elaborated by Ptolemy. For Metochites, one must

master the proofs; for Meliteniotes, an official voice of the Church of Constantinople, learning the procedures to use the tables is good enough. On this account, the contradictory view on astronomy, which in Alexandria was generated by the betrayal of Platonic ideals, was repeated in late Byzantium when interest in the *Almagest* was revived by Metochites. The interplay between geometrical proofs and the use of the tables to reach the contemplation of the heavens resembles the state of the art inherited from Alexandria. Of course, aside from observing scholarly and official recommendations, the practice of astrology spread due to its applications in medicine and warfare, as well as the desire for foreknowledge amid a time of crisis, as the Ottoman conquest moved ever closer.

## Comparisons and Final Remarks

In light of the concept of the hybrid, this article has surveyed the history of pre-Copernican astronomy within the three different historical and cultural contexts of Alexandria, Baghdad, and Constantinople. The field of inquiry on hybrid knowledge and the history of astronomy undoubtedly needs to be further enriched: on the one hand, facets of hybridity have been detected in the philosophical or socio-political aspects of astronomy's cross-cultural history; on the other hand, those features pertaining to mathematics and instrumentation will be the subject of further research. At any rate, already some partial conclusions can be drawn here. By comparing the three case studies chosen for this paper, two main notions of hybridity have emerged: 1) the hybridity of astronomy as a discipline; and 2) hybridity with regard to the traditions from which astronomical knowledge stemmed. They can be considered common lines of reading within the historical time frame with which the current study has engaged. Along these lines, a comparison of the aforementioned case studies suggests further and more extensive conclusions, which I provide in the following.



The success of Ptolemaic works in Alexandria between the second and fourth centuries can be understood as the outcome of Ptolemy's reliance on a hybrid heritage: the achievements of Greek and Babylonian scholars. As has been shown, it is historically apt to consider Ptolemaic astronomy as a whole that consists of the *Almagest* and the *Tetrabiblos*, viz. mathematical astronomy and astrology. The latter, being a combination of mathematical astronomy and divination, drew criticism in all three historical contexts, due to its scientific status. The combination of analogical reasoning drawing from previous results based on geometrical proofs can be seen as a form of hybrid knowledge itself. The habit of avoiding the geometrical proofs of astronomy in order to focus on tables is a well-documented trait of the social history of astronomy; as a betrayal of the Platonic ideals of Ptolemy, it had repercussions on the history of the epistemology of astronomy. In Alexandria, Baghdad, and Constantinople, a strand of criticism against astrology was established on the grounds of the unreliability of the mathematics on which (bad) astrologers were making predictions. Accordingly, the recommendation to study theorems and proofs of astronomy in order to become a good astrologer became a necessity that would endure in the history of astronomy until astrology was later demoted from the academic disciplines. Notably, the astronomer Regiomontanus, whose work was of fundamental importance for the future advancements of Copernicus, complained about the inaccuracy of some astrologers in his renowned lecture of 1464, and recommended the study of mathematics because astrology is the queen of mathematical sciences, granting its practitioner access to divine realms (Rutkin 2019, 369–373).[17] The habit of relying on astronomical tables, aside from contributing to the proliferation of bad astrologers in each of the cultural contexts examined above, generates an epistemological misunderstanding in fourteenth-century Constantinople. According to

[17] On Regiomontanus' lecture see also (Swerdlow 1993), (Byrne 2006), (Malpangotto 2008, 133–146), (Goulding 2010, 8–10), (Omodeo 2021).

the Byzantine sources on Ptolemaic astronomy, teaching in geometrical proofs and teaching in procedures were considered equivalent. The statements of Byzantine authors should likely be taken with a pinch of salt: they were inserted into rhetorical premises to astronomical treatises and their function was mainly to demonstrate the erudition of their authors. At any rate, with the benefit of hindsight, Metochites and Meliteniotes are the only sources on the epistemology of Ptolemaic astronomy that have come down to us from late Byzantium, and they prove to be contradictory.

Meliteniotes' *Three Books on Astronomy*, combining Ptolemaic and Islamic astronomical knowledge, employed the rejection of astrology as a tool to make "foreign knowledge" acceptable to his Christian Orthodox readership. In this instance, astrology's hybridity was used to generate a hybrid work, which led to non-Byzantine knowledge gaining official acceptance for the first time.

When religious factions such as the hesychasts (Christian Orthodoxy) and the traditionalists (defenders of Quranic doctrine) faced the hybridity of astrology as a discipline, the controversy between them and advocates of the full potential of astrology shifted into a dispute about the correct way to reach a contemplative status of divinity. Both factions (Christian hesychasts and Islamic traditionalists) defended their respective positions by recalling the hybridity of astronomy in terms of its tradition: in both cases a pagan (and Hellenistic) one. At a general level, ninth-century Baghdad and fourteenth-century Constantinople saw the formation of factions who considered astrology and monotheistic faith to be incommensurable, by labeling astrology a "foreign science," thus potentially damaging the faith of the receiving culture: embracing astrology would have meant accepting determinism and the denial of free will, a position which would have been at odds with the teachings of Islamic and Christian faith. The Mutazilites, instead, attacked astrology on the grounds of it being a foreign science because they deemed it unfounded compared to their conception of Greek sciences. In the Mutazilite worldview, astronomy's hybridity as a discipline and as a tradition merged.



After the achievements of the Alexandrian tradition and the betrayal of Platonic ideals with regard to astronomy, the hybrid knowledge of the Ptolemaic heritage was repeatedly reconceptualized in Aristotelian frameworks (as in Abū Maʿšar, Metochites, Meliteniotes), but the elaboration of the Ptolemaic conception of becoming god-like had different outcomes: Abū Maʿšar was a compatibilist, whereas Metochites and Meliteniotes conceived of astrology as denying free will.

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