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Conformément aux observations d'Hipparque: le Papyrus Fouad inv. 267 A by Jean-Luc Fournet and Anne Tihon, with Raymond Mercier

Publications de l'Institut Orientaliste de Louvain 67. Louvain-la-Neuve: Institut Orientaliste de l'Université Catholique de Louvain, Peeters, 2014. Pp. iv + 190. ISBN 978–90–429–3021–6. Cloth €50.00

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P.Fouad 267A is one of the most important new pieces of documentary evidence concerning the Greco-Roman astral sciences to be published in this century, and one of the more historically interesting single pieces of papyri of this type that is currently known. It provides a glimpse into aspects of astronomical theory and astrological practice of the second, or early third, century that we do not have from any other source. Hence, Fournet and Tihon's book, which contains a text, French translation, and study of *P.Fouad* 267A, will be of great interest to anyone working on the history of Greco-Roman astronomy.

The book has the following sections:

(1) papyrological information: physical description, dating based on orthography, discussion of the attested abbreviations, individual characteristics of the writer—including orthography, morphology, and syntax (J.-L. F.) [9–17];
(2) color photographs of recto and verso (J.-L. F.) [20–21];
(3) facing diplomatic and normalized transcriptions (J.-L. F.) [22–25];
(4) a French translation (A. T. with J.-L. F.) [26–30];[1]
(5) critical notes on the edition, keyed to the lines, including references to similar instances and parallel cases (J.-L. F.) [31–41];
(6) critical notes on the translation, keyed to the lines, including references to similar usages in known works (A. T.) [42–52];

[1] A preliminary English translation had already been given by Tihon 2010, and now a new English translation based on the full edition in this book has been provided by Jones 2016.

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(7) and interpretation of the text, sectioned into themes loosely following the organization of the material in the papyrus itself (A. T.) [59–107];
(8) complementary notes, of a few pages each on average, treating topics introduced in the papyrus such as the epoch of Hadrian, a cycle of 30,000 years, an observation by Hipparchus, different lengths of the year, and two very useful tables that summarize all of the numerical and chronological information contained in, and immediately derivable from, the papyrus (A. T.) [11–137];
(9) a conclusion (A. T.) [141–144];
(10) a glossary of Greek terms [144–151];
(11) a reconstruction of different tables that might underly the three computations of solar longitude found in the papyrus along with an analysis of possible solar models underlying the numbers found in the ancient source (R. M. in English) [156–175];[2]
(12) a bibliography, color photographs of details, an index, and a table of contents [177–190].

P.Fouad 267A is a single leaf from an unprovenanced codex, 15cm by 13.4cm, from which both the top and the bottom are missing. It is dated after AD 130 to the later second or third century [9–12].[3] To this we may now add *PSI* 1674 (inv. 2006), which was recognized by M. Stroppa as being related to *P.Fouad* 267A, and has now been studied and edited in Fournet and Tihon 2018.[4] *PSI* 1674 is a 5cm by 5.8cm piece of the same codex folio, which was originally located above *P.Fouad* 267A. *PSI* 1674r contains four partial lines of a text originally found above that in *P.Fouad* 267Ar, lines that are written in a formal, bookish script, whether by the same hand as wrote *P.Fouad* 267A or another. These lines include some words otherwise found in astrological writings [Fournet and Tihon 2018, 99].

P.Fouad 267Ar appears to begin with a new section written in a different and more private, or informal, script. It is titled 'On the Sun' and discusses solar theories and some details of the instructions that an unnamed 'he' set out for

[2] Mercier's tables, and the models he used to derive them, have been discussed and questioned by Jones 2010b and 2016, and Duke 2015. (Despite the published dates, Jones 2016 appeared before Duke's review.)

[3] On the basis of a new part of the papyrus, the authors prefer a date in the third century [Fournet and Tihon 2018, 100].

[4] A short notice announcing the find, along with a partial English translation, had appeared two years before this [Tihon and Fournet 2016].

computing solar position for a given nativity according to three methods, or models, that use, or one of which uses, an epoch prior to a dated observation by Hipparchus. This is followed by tables that set out three computations of mean motions.

The mean longitude of the sun is calculated according to three different years—a sidereal year, called 'from a point' (« ἀπὸ σημείου »), of 365 4′ 309′, or 365 ¼ − ⅓₀₉, days;[5] a 'uniform' year (« ὁμαλός »)[6] of 365 4′ days; and a tropical year (ἀπὸ τροπῶν) of 365 4′ 102′ days.[7] The text then mentions a correction for precession from the 'time of Hipparchus', as well as a shift from the epoch of the table to the 'observation made by Hipparchus'. The date of Hipparchus' observation is preserved and converts to 26 June 158 BC, making this an otherwise unattested observation of a summer solstice.

A set of computations of the three solar longitudes are made for a nativity (γένεσις) with a date stated both in a year of Hadrian and a year 'according to the Egyptians', which, however, are one day off from each other, but which should both convert to 8/9 Nov AD 130, the date actually used in the computations [64–65; Jones 2016, 83]. The tables that set out these calculations, the values of which were drawn from tables of mean motion, make it clear that that the epoch of the mean motion tables was 37,500 years before the date of Hipparchus' solstice observation of 158 BC, and that they were laid out in periods of $10{,}000^{y}$, $1{,}000^{y}$, 25^{y} 1^{y}, and so on—making these tables inefficient for most practical astrological calculations, but reminiscent of Ptolemy's claim that people tried to exhibit uniform circular motion 'through the so-called eternal table-configurations' (« διὰ τῆς καλουμένης αἰωνίου κανονοποιίας ») [Heiberg 1898–1903, 2.211].

This is followed by *PSI* 1674v, in the same hand as found in *P.Fouad* 267A, which, although heavily abraded and quite fragmentary, mentions a number of topics that we might expect to read between the recto and verso of *P.Fouad* 267A—a table of rising times, an observation by Hipparchus, tropical position, solar anomaly, the sexagesimal value of a sidereal longitude

[5] I use a standard notation for proper parts, such that $n' = 1/n$, often written as $\bar{n}$ in scholarship on Egyptian sources. Such is the text, but there is probably some error here, since this value better suits the tropical year [70: Jones 2016, 81].

[6] This word is used by Ptolemy to denote mean motion—which, since all three of these years are mean, in Ptolemy's usage, makes its meaning, or its astronomical function, here somewhat uncertain.

[7] Again, our author has apparently confused the sidereal and tropical years [70: Jones 2016, 81].

that can be (and indeed had been [82; Jones 2016, 80]) recomputed from the values given in *P.Fouad* 267Av, hourly motion, and so on.

Finally, this continues in *P.Fouad* 267Av, which is also difficult to interpret but deals, after a tantalizing possible mention of the name 'Menelaus' [37], with a correction to the tropical longitude and a computation of the duration of nighttime in equinoctial time-degrees, using a table of rising times for the latitude of Alexandria tabulated at intervals of 1° [85–94]. This is followed by a computation involving the solar declination, followed by an obscure computation that involves entering a table whose title contains the word «μεσημβρινός» ('having to do with the meridian'), the meaning of which is unclear [94–98] but which may have been astrological.

There can be no doubt, from both papyrological and technical perspectives, that *PSI* 1674 belongs to the same codex, and that *PSI* 1674v belongs between *P.Fouad* 267Ar and *P.Fouad* 267Av and helps to flesh out our understanding of this material. Together, *P.Fouad* 267A and *PSI* 1674 provide us with an intriguing glimpse of theory and practice in the astral sciences that, although contemporary with, or more likely later than, Ptolemy's work, seem to be uninfluenced by either the *Almagest* or the *Handy Tables*.

Along with the many, and still not fully resolved, theoretical questions that this material raises, we have a number of interesting practical and historical questions that can be directed to these documents. We are interested to know who wrote this material, when, and to what end. Originally, Fournet and Tihon considered *P.Fouad* 267A to be lecture notes written shortly after AD 130 [12, 16–17, 141–144], and they were followed in this by Jones [2016, 78]. But in their publication of *PSI* 1674, they point out that this is less certain, and argue for a later date for the codex [Fournet and Tihon 2018, 100]. Nevertheless, the many errors and oddities of *P.Fouad* 267Ar + *PSI* 1674v + *P.Fouad* 267Av, of which only a few have been mentioned here, still make it unlikely that this is copy of a treatise, or indeed a copy of some previous work. Perhaps we have here a workbook of a practicing astrologer, in which astrological treatises, or passages thereof, and methods for computing positions are variously set out. Or perhaps an astrologer copied out a method of computing positions onto a final, or empty, leaf of a codex in which a treatise had been written. Then, the example nativity of AD 130 may have been taken from a book that our astrologer was studying, or was perhaps used as an example in a private lesson that our astrologer was trying to follow—not very successfully.

In any case, this book by Fournet and Tihon is a fine piece of scholarship on an obscure and difficult but important piece of original evidence. It will be of great interest and value to anyone working on the exact and astral sciences in the Greco-Roman world.

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Laws of Heaven — Laws of Nature: Legal Interpretations of Cosmic Phenomena in the Ancient World edited by Konrad Schmid and Christoph Uehlinger

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This volume, the proceedings of a conference, raises issues which require review and debate, much to the credit of the editors and authors.[1] The core of the volume deals with the idea that the cosmos is guided and governed by laws which are attributed to a concept of 'nature'. This conceptual framework has historically been associated with the Greek terms 'nomos' («νομός») and 'physis' («φύσις»), within the context of early Greek philosophy. The question is whether similar ideas can be found in earlier, and more geographically widespread, intellectual circles of thought in Mesopotamia and Egypt, and in the Bible. This turns out to be a challenging proposition. Before turning to the specific contributions in this volume, it is important to consider some general methodological issues.

The basic problem here is that the central research question investigates terminology most appropriate for Greek philosophy, such as the concept of 'nature' itself, or whether nature was governed by laws or unspecified rules, and finally, whether 'natural law' as an ethical concept was universal in antiquity (see Rochberg's discussion [21]). These concepts have to be evaluated in tandem with ideas of divine law and divine will, which offer parallel alternative notions of how the cosmos is governed. To this end, the present volume turns to major Mesopotamian cosmographies such as *Enūma Eliš* or *Atrahasis*, while investigating significant similarities between legal formulations and omen literature from Mesopotamia, which together offer the richest array of source material to address these questions of 'laws

[1] The preparatory work for this review was carried out under the ERC Advanced Grant Project No. 323596 *BabMed*.

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of heaven, laws of nature'. The Akkadian myths are thought to reflect divine governance of the cosmos: for example, Marduk's defeat and execution of Tiamat resulting in the creation of man (the creation of woman is entirely missing from the account) and leading to Marduk's arbitrary control of heavenly bodies and how they move. The extensive Akkadian omen literature relates to this research not because of any direct connection with mythology but because omens, oracles, and prophecy were thought to convey divine will and divine thinking: they were personal messages from divine overlords to human society below. Because omens are expressed within casuistic legal formulations of 'if A then B', which associate signs with events (see Uehlinger's comments [163]), omens can be seen to represent divine decisions, judgments, or rulings, where the gods are as judges of human society (according to Rochberg [28]).

There is a chronological development of Akkadian literature which has not been discussed in this volume but nevertheless needs to be acknowledged. Legal codes (famously that of Hammurabi) reached their apogee in the Old Babylonian period from the early second millennium BC, with excerpts from Hammurabi's codex being copied as part of the school curriculum. Meanwhile, omen literature was not only well attested in the earliest records[2] but continued to develop as a large component of Akkadian 'science', only to be superseded in the mid-first millennium BC by astrology, although classical omen texts continued to feature within the curriculum.

By contrast, the myth of *Enūma Eliš* was a relative latecomer as a literary work, probably dating to the end of the second millennium BC, and as such reflects current Mesopotamian cosmology but does not inspire it. Moreover, this long development within Mesopotamia has to be seen in contrast with what was happening in both Egypt and the Levant.[3] As far as one can tell from Franziska Naether's contribution to this volume [52–72], Egyptian cosmographies are tailored to the topography of Egypt (and the Nile) and are essentially theological, while little in the way of technical omen literature seems to exists before the Ptolemaic period.[4] The Bible, on the other hand,

2 For Old Babylonian examples of divination, see George 2013.

3 Jeffrey Cooley refers to the Bible as reflecting a 'Canaanite' point of view [116–117], but this is misleading, since Canaanite mythologies differ significantly from biblical accounts.

4 Naether does not clarify the dating of all of the texts she cites, but it should be noted that the idea of casuistic omens could have potentially been introduced any time after the Assyrian conquest of Egypt.

offers important marginal information in the form of highly developed prophetic texts, some of which refer to what could be interpreted as 'natural law' [see Schmid, 12–13]. Biblical prophecy is far more elaborate than any of the prophetic pronouncements known from Mesopotamia, which hardly addressed moral questions and concentrated on immediate questions of political expediency.[5]

Even more important, the Bible describes a society with its moral code based on revelation, i.e., God speaking directly to Moses and letting him know exactly what is expected, without much ambiguity. With revelation, as with oracles or prophecies, one can dispense with the cumbersome machinery of liver-divination and other forms of forecasting the future. This may be the actual reason behind Uehlinger's conclusion that the biblical 'formulation of "laws of nature" reflects a rather different world and world-view from their Mesopotamian cousins' [167]. Uehlinger suggests that this may be because of differences in authority which were contested between Mesopotamia and Palestine, or alternatively that appropriate institutional infrastructures for 'science' were not available in the Levant as in Mesopotamia or Egypt [169]. However, the fact that revelation played such a central role in biblical cosmology obviated the need for highly technical means of fathoming divine will, such as liver-divination or even astrology. There were, however, exceptional equivalents to biblical revelation from Mesopotamia, both from a particular source. A Late Assyrian period legend recounts an apocalypse of the antediluvian sage and king Enmeduranki, who was elevated to heaven to learn the secrets of hepatoscopy, which he then taught to his countrymen upon his return to Earth. It is clear that this legend inspired the apocalypse of Enoch, who was taken up to heaven to write 365 books about astronomy, cosmology, and correct procedures for sacrifices, which he taught to others upon returning to earth.[6] Neither of these apocalypses, however, actually communicated

[5] See Liverani 2018, 10–32, his chapters on 'God's Will' and 'Communicating with God', which emphasize the celestial and liver omens which were crucial to decision making for the Assyrian king. The genre of oracle questions, which address direct 'yes' or 'no' questions to the gods of judgments, Šamaš and Adad, were probably ancillary procedures which accompanied liver-divination rather than replacing the complex techniques of other forms of forecasting.

[6] The clearest description of Enoch's apocalyptic journey appears in 2 (Slavonic) Enoch, not consulted by Matthias Albani in his contribution to this volume. See Badalanova Geller 2010. For the text of Enmeduranki's apocalypse, see Lambert 1967b, and for the connections between Enmeduranki and Enoch, see Borger 1974 and Sanders 2017, 16–18, 55, as well as Annus 2018 for a review of Sanders.

divine will *per se* but were intended to reveal secret knowledge to mankind about the cosmos, and both Enmeduranki and Enoch remained marginal to the mainstream of Mesopotamian and Jewish literature.

Even superficially, it should not surprise us that neither Egypt nor the Bible offers the right kind of evidence for 'laws of nature' or 'natural law', since revelation, prophecies, and even oracles all look towards theological models for explaining the cosmos.[7] Laws of nature, by way of contrast, are used to explain the mechanisms of the ecological and social environment without referring directly to the divine or deities, or indeed precluding their existence.

The clearest statement of current thinking on the concept of nature, laws of nature, and natural law—and the centerpiece of this volume—is that of Francesca Rochberg [21–39]. It is now somewhat overtaken by her recent book, *Before Nature* [2016], which advances her arguments in much greater detail. But the essence of her contribution is that the concept of law and legal reasoning can be projected onto the physical environment (as laws of nature) and that a corollary to this line of reasoning is the concept of natural law, which is an ethical concept 'grounded in a commitment to a universal human reason' [21]. Rochberg provides lucid descriptions of legal metaphors drawn from actual historical and juridical disputes which were applied to divine figures, such as the sun god Šamaš and the storm god Adad, acting as judges and as the subjects of incantations and oracles. The terminology of omens, such as 'purussu' ('verdict') referring to the omen apodosis, equates omen decisions with legal judgments. The question is whether, throughout Mesopotamian history, the gods were always the drivers behind omens, or whether a concept of laws of nature or natural law could have developed *independently* of divine interference, and without reference to gods, at the same time as pre-Socratic philosophers were contemplating similar thoughts.

To answer this question, let us turn first to the question of natural law in Mesopotamia and whether such a notion ever existed. The idea of natural law is rooted in Stoic philosophy [23f],[8] without any evidence that it derived from any Near Eastern influence, perhaps because there was none. The ethical force behind natural law is that mankind should be able to

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[7] Much attention has been paid in this volume to the work of Edgar Zilsel, discussed both by Konrad Schmid [10–12] and Christoph Uehlinger [165], but Francesca Rochberg rightly points out [37] that Zilsel's theologically grounded arguments from the Bible are weakened by his lack of familiarity with Mesopotamia.

[8] But see Rochberg's quotations from Cicero [34f], that natural law was created and enforced by God, so that it was never divorced from the divine.

distinguish instinctively between right and wrong, i.e., without benefit of the Ten Commandments or similar devices. Since Mesopotamia lacked a notion of universal revelation,[9] the guidelines for correct human behavior had to be deduced from other sources, e.g., Šurpu incantations and rituals which listed numerous taboos in the form of an oath (*māmītu*).[10] (The binding oath—taken by ancestors—identified punishable behavior which was offensive to gods and proscribed for succeeding generations [Geller 1980].)

Clearly, there were rules which could be learned to influence human behavior, which would be noticed and enforced by divine authority and interference in human affairs. In this sense, one can discount any notions of natural law, which assumes an innate ability to comprehend divine will and correct social behavior. Hence, examples provided by Rochberg of gods as adjudicators of human behavior can be explained as direct master-client relationships, in which gods judge and punish unacceptable behavior, without imposing any additional philosophical layer of human rationale determining what gods want or prefer. In fact didactic compositions such as *Ludlul,* describing the plight of the righteous sufferer, show that the system is far from perfect.[11]

There is also a serious flaw in the discussion of nature and laws of nature in this volume which has been overlooked by all contributions, with one exception: Matthias Albani, who points out,

> Probably for the first time in Mesopotamia, man recognized the regularity of natural processes in the firmament and did astronomical computations. This revolution in human thinking went along with significant changes in the ancient religions.[12]

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[9] As mentioned above, Enmeduranki's exceptional journey was for the purpose of acquiring the secrets of liver divination, but not for revealing laws of nature or moral instructions, or even divine will.

[10] *Chicago Assyrian Dictionary* M/1 *s.v. māmītu*, 189–195. The oath was a fundamental tool for enforcing divine law, since a universally recognized tenet of society is that gods do not tolerate a false or violated oath. See Van der Toorn 1985, 52–54, a study which remains the best treatment of moral standards from Mesopotamia with useful comparisons with the Bible.

[11] See Lambert 1967a, 21–62 and Oshima 2014.

[12] *Wahrscheinlich hat man erstmals in Mesopotamien die Gesetzmäßigkeit von Naturvorgängen am Firmament wahrommen und astronomische Berechnung angestellt. Diese Revolution im menschlichen Denken ging einher mit einer signifikanten Veränderung der antiken Religionen* [123].

A revolution, indeed. The tendency to define a single unified world view for Mesopotamia is doomed to failure, since every society encompasses conflicting opinions and perspectives, and this is particularly true when chronological developments are not taken into account. The invention of the zodiac (overlooked in this volume) was a sensation, since it offered a much more exact mapping of the heavens than had existed previously, while at the same time paving the way for mathematical astronomy to make far more accurate predictions of the movements of stars and planets, even to the extent of predicting eclipses.[13] Once accurate predictions of astral phenomena could be made by the astrologers in Babylonia, who kept detailed diaries of the heavens on a daily basis over hundreds of years, the entire ideology of heavenly law was subject to revision. The previous picture of the heavens propounded by mythology—especially *Enūma Eliš*—ceased to be valid in the light of the overwhelming evidence of precise mathematical calculations. No longer was Marduk required to establish the regularity of celestial movements, and no longer in his role as Jupiter was it necessary for him to control heavenly bodies who 'sinned' by not following his orders (as described by Schmid [15–16]). Marduk's role in *Enūma Eliš* in placing the heavenly bodies in three areas of the sky, named after the gods Ea, Anu, and Enlil (see Rochberg's comments [30]), reflected an older, pre-zodiacal system of astrology known from the classic astronomical text MUL.APIN which was no longer relevant for trained astrologers. Texts like MUL.APIN continued to be studied in the school curriculum, and many inhabitants of Babylonia no doubt continued to believe in Marduk's personal control of the universe, but others understood that once one could predict with precision heavenly movements, the gods lost their numinous credibility.

In a similar vein, the biblical *ḥqwt šmym* or 'rules of heaven' [Jer 33:25, see vv. 13, 124; Job 38:33] were suddenly dated after the discovery of the zodiac, since God was no longer required to regulate the heavens. If a lunar eclipse could be forecast, the threat it posed was measurably reduced, since it had become obvious that such events were not messages sent by deities but represented the normal and regular patterns of movements of the natural order, as part of the complex celestial apparatus which operated according

[13] This point was not taken up in the contribution of Jörg Hüfner [147–161], although his comments on mathematical astronomy among the Greeks are useful, if not quite as relevant as Britton and Walker 1996, 42–67.

to fixed patterns which could be calculated and predicted mathematically.[14] The effect of mathematical astronomy was not to diminish omens or their influence, but rather to alter belief in the personal intervention of gods. As celestial observation and zodiacal calculations gradually replaced liver-divination and other, less mathematical forms of forecasting the future, the gods were likewise discretely ushered into the background, with planetary and zodiacal influences on human events being promoted into primary consideration: thus, e.g., horoscopes would refer to zodiacal signs rather than to gods. With the widespread use of zodiac-based astrology, references to divinities are noticeably diminished, although gods are implicitly associated with celestial phenomena (e.g., the god Marduk as Jupiter). There is, however, no suggestion in this scenario of disenchantment, but a *gestalt* that took on a different character once astronomers visualized the heavens as 'clockwork', based on a mass of new scientific data. Scholars, perhaps including those who advised the king, may have modified their perceptions of the cosmos, but many others would adhere to their traditional beliefs in divine intervention in human affairs. In Greece, we accept competing schools of thought (Stoics, Epicureans, Methodists, and so forth) as normal, but in Mesopotamia we usually advocate a single doctrine, as if everyone shared a common opinion. The main discourse of this volume could have taken a different direction had sufficient attention been paid to innovative thinking in Mesopotamian at roughly the same time as Presocratic philosophers in Greece were contemplating the cosmos.

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[14] This viewpoint opposes that of Jörg Hüfner [155], who thinks that mathematical astronomy had little effect on how omens affected royal decision-making. On the other hand, this might provide a positive answer to Matthias Albani's question: 'To what extent is this insight into nature's compliance to causal laws in the book of Enoch an "answer to Job"?' ('Inwiefern ist diese Erkenntnis der Naturgesetzlichkeit im Henochbuch eine "Antwort auf Hiob"?').

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Menelaus' *Spherics*, composed in the 2nd century AD, uses earlier work in spherical geometry, particularly Theodosius' *Spherics*, to develop a theory of the spherical triangle as the basis of a new approach to spherical geometry, trigonometry, and astronomy—that is, to the ancient mathematical discipline called *spherics*.[1] Despite the originality, and applicability of this work,[2] there is no evidence that it was ever studied seriously in its entirety in the ancient period, and only fragments of the Greek text, which are preserved as quotations in later texts and scholia, survive.[3] Indeed, it is not even certain that Ptolemy used this text when he was developing his approach to spherical astronomy in *Alm*. 1.13–2.13 and 8.5–6.[4]

Menelaus' *Spherics* can be divided into three sections. The first treats the geometrical properties of spherical triangles by developing analogies between these and the properties of plane triangles that are developed in Euclid's *Elements*. The second shows how certain arcs of spherical triangles can be related to the lengths of chords related to them and, using a theorem

1 This review is an expansion of my review of the same book for *Bryn Mawr Classical Review* [Sidoli 2019], which had a strict word limit.

2 The potential usefulness of this work to spherical astronomy, which was not exploited in any surviving text in Greek, is explained by Nadal, Taha, and Pinel 2004.

3 The Greek fragments are collected and studied in Bjørnbo 1902, 22–24 and Acerbi 2015. It is possible that Menelaus himself applied the methods developed in his *Spherics* in a lost work on spherical astronomy. But, if so, this approach was not adopted by Ptolemy or any other known Greco-Roman author.

4 Bjørnbo 1902, 92 raises doubts that Menelaus wrote the so-called Menelaus (Sector) Theorem, a line of thinking that I have developed more fully in giving a number of further arguments [Sidoli 2006]. If Menelaus did not write the Sector Theorem, then nothing else compels us to believe that Ptolemy used his text at all.

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known as the Sector Theorem (Menelaus Theorem), provides a method for the metrical treatment of the arcs of great-circles. The third section develops these methods for application to problems in spherical astronomy, a field that investigated issues such as the length of daylight and nighttime, and the rising times of stars or arcs of the ecliptic.

The book under review is a valuable contribution to our understanding of the history of Menelaus' *Spherics* in the medieval period, as well as to the mathematics developed in the treatise. The first part deals with the various medieval versions of, and witnesses to, Menelaus' treatise; the second part provides mathematical commentaries, including texts and translations of remarks by medieval scholars; the third part gives a critical edition of a fragment (breaking off in prop. 36) of an early Arabic translation (**A**) [408–483] and the al-Māhānī/al-Harawī version (**M/H**) [500–777].[5] There is also a postface on spherical geometry and its history. The mathematical commentaries in the second part are useful for understanding the text and the critical editions, and the many partial editions and translations of medieval sources are an extremely valuable contribution to our state of knowledge about this text.

The **M/H** version of the *Spherics*, edited and translated, along with **A**, in 'Part III: Text and translation', is historically quite interesting, but al-Harawī's many interventions, along with his failure to grasp some of the mathematical details, introduce nearly as many problems as they resolve.[6] Al-Harawī has added two historical and philosophical prefaces to the text [500–505, 684–685]; inserted a number of lemmas [686–695], one of which is mathematically incorrect [692–995]; rewritten some propositions, sometimes incorrectly; and introduced some terminological innovations, which cause as much confusion as help and are not used in the other major medieval versions of the text [688–691]. Hence, this version of the treatise cannot be taken as a reader's text, and Naṣr Manṣūr ibn ʿIrāq's version, **N**, edited by Krause [1936], and the revision by Naṣīr al-Dīn al-Ṭūsī, available in Hyderabad series 1940–1941 and reprinted by Sezgin [1998], **T**, must still be consulted in order to understand the mathematics involved.

Another welcome contribution of Rashed and Papadopoulos' book is 'Part II: Mathematical commentary', which explains the mathematical details of

[5] I use bold letters, **X**, for versions of the text for which we possess one or more witness(es), and italics, *X*, for versions which have been lost, or are a matter of conjecture.

[6] For an overview of al-Harawī's version of the text, see Sidoli and Kusuba 2014.

the text and explains each proposition, including the relevant scholarship of both Ibn ʿIrāq and al-Ṭūsī. Hence, this section of the book provides a fairly clear picture of the mathematical issues involved, along with the interpretations of this text by two of its most important medieval readers.

In part 1, Rashed and Papadopoulos give an introduction to Menelaus and his work, and then discuss the text history of the *Spherics* in the medieval period. Our understanding of the relationships between the various medieval versions of the the treatise is still largely due to the scholarship of M. Krause [1936]. Rashed and Papadopoulos give a reevaluation of this material but the positions for which they provide clear evidence were already established in Krause 1936 and Hogendijk 1996. Their new suggestions remain conjectural and are, in my opinion, not convincing.

Since the situation with the medieval version of this treatise is rather involved, it may help to summarize this before describing Rashed and Papadopoulos' contribution. There are currently three known, complete, relatively early Arabic versions of Menelaus' *Spherics*:

- the version by al-Māhānī/al-Harawī, **M/H** [500–777];
- that by Ibn ʿIrāq, which has been edited in Krause 1936, **N**; and
- a revision, **T**, by al-Ṭūsī from **M/H** and **N**.

Furthermore, there is also

- a newly discovered fragment **A** [408–483], as well as
- a Latin version by Gerard of Cremona, **G** and a Hebrew version by Jacob ben Machir, **J**,
    - both of which Krause argued were produced from the same, now lost, Arabic version, whose existence he conjectured, *D*.

Krause showed that if *D* had indeed existed, it must have been made from a source that contained the al-Māhānī version before al-Harawī corrected it, *M*, for the first part, and the source of **N** for the second part.[7] The existence of *D* was then further confirmed when Hogendijk [1996] showed that Ibn Hūd, in composing his *Perfection* (*al-Istikmāl*), had worked from a version of the *Spherics* that had these same characteristics—namely, the first part from *M* and the second part from the source of **N**. As for the translators, Krause noted that the Hebrew manuscripts credit Isḥāq ibn Ḥunayn with the translation and claimed that the source translation for **N** must have

[7] At the time, Krause believed that the Sector Theorem, prop. 3.1 (prop. 66 in **M/H**) in *D* was not from the source of **N**; but it was later shown that this view is not tenable: see Lorch 2001, 332–334 and Sidoli 2006, 50.

been this translation, *bH*,[8] while the source translation for **M/H**, say, *U*,[9] was taken to be anonymous, and the translation mentioned in some of the marginal commentaries by Abū ʿUthmān al-Dimashqī with the corrections by Yūḥannā, *D/Y*, he considered to be completely lost.[10]

Much of the first part of Rashed and Papadopoulos' book confirms this overall picture, with two proposed changes. For example, they reconfirm that the source-translation for **M/H** and **N** differ, that **G** is based on *M* and the source of **N**, and that the source used by Ibn Hūd has the same characteristics as that for **G**. On the other hand, they believe that:

(a) the newly discovered fragment **A** is a translation unrelated to anything we previously knew about—that is, that **A** is not Krause's *U*—which, as I will argue below, is unconvincing, and that

(b) the source for **N** is not Krause's *bH* but rather *D/Y*. This is a possibility, but because they have not shown (a), it remains fairly unlikely and is contradicted by the direct testimony of the Hebrew sources.

Moreover, instead of directly addressing the issue of Krause's proposed *D*, they, strangely, raise the possibility of such a source as though it is a question arising from their own work and not already a concrete proposal argued for by both Krause and Hogendijk.

As for (a)—namely, the proposal that the new fragment that Rashed and Papadopoulos have discovered, **A**, is not the base translation for **M/H**—I do not find it convincing. In fact, I find nothing in the comparison of this fragment with **M/H** that rules against the likelihood that **A** is Krause's *U* and that it was indeed the source-translation for the production of **M/H**. There are, of course, many differences. The diagrams have been redrawn and relabeled and the letter-names are changed such that they are introduced in *abjad* order. The diagrams in **A** are, in fact, those included at the back of one

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8 Rashed and Papadopoulos note eight Hebrew manuscripts that mention the name of the translator [19 nn50, 51]. The claim in two of these that the translator was Ḥunayn ibn Isḥāq is a natural slip of replacing the less famous son with the more famous father.

9 Krause calls this $\ddot{\mathrm{U}}_1$.

10 Krause 1936, 35 notes one mention of this version in the margin of a copy of **T**. Rashed and Papadopoulos have since found two other mentions of this version—one in a margin of a copy of **T** and the other in a margin of a copy of **M/H** [19–20]. In fact, these new citations of *D/Y* are both the same gloss and may simply have been transmitted as marginal scholia rather than drawn from independent inspections of *D/Y*.

of the **M/H** manuscripts, *BL Or*. 13127 f. 52a, and said to be 'according to the first composition' («على الوضع الأول»).[11] There are also extensive differences of terminology [402–403] and three minor differences in the way that the argument is developed [props. 4, 11, and 14]. But all of these changes could be included within the scope of al-Harawī's claim that the text has been corrected in 'expression' («لفظ»), 'sense' («معنى»), and 'proof' («برهان») [503]. The three substantive differences between **A** and **M/H** in the mathematical arguments can all be explained as the interventions of the editors of **M/H**. For prop. 4 in **A**, only half of the proposition is set out in the exposition and proved, although the text of the proof is corrupted. Hence, the changes in **M/H**, also found in **G**, involve setting out the full exposition and completing the proof [29–30, 417 nn8, 10]. That is, the differences between **A** and **M/H** are easily explained by supposing that al-Māhānī corrected a garbled source—which description **A** here appears to fit. For prop. 11 in **M/H**, one of a pair of converses is shown, whereas the other converse is asserted, while in **A** only the other converse is stated and shown [33–35, 426 n23]. Since the first application of prop. 11 in the following theorem uses the converse not shown in **A** [248: see Krause 1936, 130], it is clear why a mathematically inclined editor would change the text to the version found in **M/H**, so that both converses are clearly stated. Finally, for prop. 14, **M/H** introduces a condition to the theorem, also found in **G** and **J** but not in **A** or **N**, which, however, is not necessary. Rashed and Papadopoulos believe that this is an indication of a different source [37, 430 n27, 532 n11]. But it can just as well be read as an intervention on the part of al-Māhānī—because, as pointed out by Rashed and Papadopoulos, the more restricted statement is enough for the application of this theorem in the following theorem [538: see Krause 1936, 134]. Hence, all three of these differences are explicable in terms of mathematical interventions on the part of al-Māhānī. On the contrary, the overall development of the propositions is the same in **A** and in **M/H**, including the peculiar props. 8 and 9. Moreover, the references to 'the ancient translation' («النقل القديم») or 'the first composition' («الوضع الأول») in the scholia to **M/H** point to material that we find in **A** [565, 595] and the diagrams at the end of *BL Or*. 13127. The wording of these references

[11] The situation with the diagrams in *BL Or*. 13127 is fully described in Sidoli and Kusuba 2014, 158–159. The description [492–493] by Rashed and Papadopoulos is somewhat misleading. There are slight differences between the diagrams in **A** and *BL Or*. 13127 in props. 12 and 35; and in the labeling for props. 18, 22, and 23. But otherwise they are identical.

is sometimes a little different, but the content is the same; and al-Harawī indicates that there was more than one correction of the source-translation in circulation in his time [503]. Consequently, we should not expect perfect verbal agreement. In fact, the places where **A** agrees with **N** against **M/H** can all be just as well, if not better, explained by the interventions of al-Māhānī than by the supposition of a different source. All in all, I see no compelling reason why we should not believe that **A** is a fragment from the tradition of the source translation that served, in some way, as the basis for **M/H**—in a word, that **A** is in fact a manuscript from the tradition of Krause's *U*.

As for (b), the thesis that the source translation for **N** was al-Dimashqī's *D* as opposed to Isḥāq's *bH* is possible, but not proven. Isḥāq is credited with some six other translations of Greco-Roman mathematical texts and al-Dimashqī is credited with one other full translation—although a rather advanced one—and perhaps some books of the *Elements*, so that either man is a possible candidate for the translator of the source of **N**. The argument in support of following Krause is that Isḥāq is directly associated with this version in the Hebrew tradition [see 17 n8], whereas the *D/Y* version is only mentioned in three glosses (to manuscripts of **T** and **M/H**), two of which are, in fact, the same, although in different versions of the text—and it is unclear from these glosses that there was a full, independent translation by al-Dimashqī, *D*, in circulation. The advantage of following Rashed and Papadopoulos is that we would not have to accept that the *D/Y* version has been completely lost. On the other hand, we would either need to suppose that *bH* is the basis of **M/H**—which is Rashed and Papadopoulos' position—or that *bH*, which was produced by one of the most famous translators of mathematical texts, has been lost completely, neither of which seems to me to be likely. The reason for my holding that it is unlikely that *bH* is the source of **M/H** is that al-Harawī says that the source translation was poor—which is also clear from the text itself, as was argued directly by myself and Kusuba [2104, 193–194]—whereas, based on what we know from other sources, Isḥāq's translations of mathematical works were generally fairly good. Indeed, **A** is much sloppier than any of the translations that are securely attributed to Isḥāq. Moreover, as was argued above, it is likely that **A** is a copy of the source translation for **M/H**, which would mean that in order to accept Rashed and Papadopoulos' claim we would also have to accept that a translation by one of the most famous translators of Greek mathematical works has disappeared without a trace.

These criticisms do not in any way diminish the value of Rashed and Papadopoulos' work, though their lack of acknowledgment of the work of previous scholars is disappointing. Sometimes they simply neglect to mention significant work, such as the recent collection of scholia to the *Almagest* citing the Greek text of Menelaus' *Spherics* made in Acerbi 2015. In other cases, they make no mention of the fact that some of their positions have already been put forward, and argued for, by others. For example, they argue at length that the first part of **G** is based on the same source as **M/H** (that is, *M*), whereas the second part is based on the same source as **N** [26–71]. But this was established by Krause [1936]. Likewise, in the section on Ibn Hūd, Rashed and Papadopoulos claim that the question of his source has 'not been correctly addressed until now' [74], though they use the same methodology as Hogendijk and come to the same conclusion—namely, that the first part of Ibn Hūd's source is from **M** and the second part from the same source translation as **N** [73–121]. That is, in both cases Rashed and Papadopoulos' actual contribution is to give further evidence, including edited texts, which serves to confirm previously established positions.

We are grateful to Rashed and Papadopoulos for their work in producing two new editions of the Menelaus' *Spherics* (**A** and **M/H**), in providing the original sources for much of the medieval scholarship on this important work, and in commenting on the overall mathematical development of the treatise. As the discussion above has shown, however, we should not read **M/H** by itself as Menelaus' text because it is a highly edited version of the treatise. In our current state of knowledge, it remains that we must read **M/H** along with both **N** and **T** in order to assess Menelaus' work fully, and we still await critical editions of the Latin and Hebrew versions before we can hope to understand the medieval transmission of the text.

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Time and Cosmos in Greco-Roman Antiquity edited by Alexander R. Jones with contributions by James Evans, Dorian Gieseler Greenbaum, Stephan Heilen, Alexander Jones, Daryn Lehoux, Karlheinz Schaldach, John Steele, and Bernhard Weisser

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From 19 October 2016 to 23 April 2017, an extraordinarily rich exhibition of over 100 items related broadly to time was held at the Institute for the Study of the Ancient World (ISAW) at New York University. The objects came from 26 international museums and collections, and included sundials of varying types, scale, and materials; clepsydras; star-globes; calendars and parapegmata; inscriptions; mosaics; sarcophagi; statuettes, reliefs; tablets; seal stamps; an altar; vessels; papyri; gems; rings; coins; and a cameo (have I missed anything?!). This book is the catalog for the exhibition.

As anyone working in the museum profession will know, it would have been a huge undertaking to get permissions to exhibit this range and type of material, to acquire the funding to underwrite and transport the objects in safety, and to plan, design, and mount the exhibits. Not surprisingly, Jennifer Y. Chi, exhibitions director and chief curator at ISAW, states in her acknowledgements to *Time and Cosmos* that the exhibition was five years in the making, and involved numerous overseas trips by herself and the curator/editor, Professor Alexander Jones, to negotiate the loans. I can only stand in awe of what they must have achieved in the actual exhibition and, since I did not manage to see it in person, be ever grateful for the exquisite catalog that accompanied the display.

The catalog includes essays by leading scholars, with an introduction by Alex Jones that situates the successive chapters in the context of the study of astronomy in antiquity.

John Steele covers Babylonian astronomy, writing in characteristically clear fashion on the means of keeping track of time from day to day *via* calendars, and on time-intervals of less than a day *via* water clocks, sundials, and the

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stars. He rounds his chapter off with a discussion of the development of the zodiac and its role in Babylonian astrology.

Karlheinz Schaldach, the leading international authority on Greek and Roman sundials, provides a chapter on his speciality. He starts with a brief history of the development of sundials, including the recent work on the new dial found in Olympia.[1] The middle of his chapter is devoted to close analyses of seven varied examples that draw us back to the exhibition itself: the Delian sundial ship; the globe sundial from Prosymna; the double vertical sundial of Delos; the oldest sundial from Pompeii; a horizontal sundial, as a prototype of Buchner's well-known reconstruction of the so-called Horologium on the Campus Martius in Rome;[2] the roofed spherical sundial from Carthage; and the astronomical clock from Salzburg. The article ends with a discussion of portable sundials[3] and the purposes of sundials.

Daryn Lehoux delivers a paper on the various ways in which calendars and cosmic cycles were incorporated into material objects and so included in daily life among the Greeks and Romans. He includes the cultic calendars of the Greeks; the Metonic Cycle of the Antikythera Mechanism; the Roman religious feast-day calendars (*ferialia*) and 'farmers' calendars' ('menologia rustica'); his speciality, the *parapegmata*; objects incorporating the week-day-cycle, at one end of the time spectrum, and, at the other extreme, the 'great year' cycles when all of the planets would return to a particular configuration. He ends with a description of the Antikythera Mechanism and a Byzantine descendant, as examples of objects that 'mechanized' the cosmos.[4]

With the end of Lehoux's chapter we are starting to tread on territory that is more metaphysical in character, and the next chapter, by Stephan Heilen and Dorian Gieseler Greenbaum, takes us more fully into this world *via* a discussion of the development of astrology in the Greco-Roman world. They use a variety of objects to illustrate different aspects of this ancient

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[1] For more detail on this, see Herrmann, Sipsi, and Schaldach 2015.

[2] On this, see the recent work by Frischer, Fillwalk, Albèri Auber, Dearborn, Kajava, and Floris 2016–2017.

[3] A complete list of such dials appears at the end of the chapter, while Talbert 2016 is now the *vade mecum* for such dials.

[4] See Allen, Ambrisco, Anastatsiou, Bate, Bitsakis, Crawley, Edmunds, Gelb, Hadland, Hockley, Jones, Malzbender, Mangou, Moussas, Ramsey, Seiradakis, Steele, Tselikas, and Zafeiropoulou 2016; Jones 2018; Lehoux 2018; Evans and Carman 2019; and Freeth 2019 for some recent work on the Antikythera Mechanism.

practice—notably the unique wooden zodiacal boards from Grand (Vosges) in France and the marble version (*Tabula Bianchini*) from Rome that were used by astrologers, but also the gems with their exquisite, miniature engravings of the planetary gods; and other astrologically related symbols. Horoscopes themselves are represented by examples on papyrus from the Louvre in Paris. Heilen and Greenbaum deal not only with birth-horoscopes, with which readers would be most familiar from their survival to the present day, but also with the lesser known iatromathematics (concerned with predictions on the causes, severity, and appropriate therapy of illnesses); elections (dealing with choosing the right time to begin an action); and interrogations (to do with seeking further information beyond simply the best time for an action).

Jim Evans is best known as an outstanding historian of ancient astronomy, whose work is characterized by a deep understanding of the mathematical bases of the science. In this catalog, however, he shows another side of his broad knowledge of astronomy as he discusses a wide range of material objects for their inclusion of astronomical symbols. These include diverse images of the celestial globe (as in the Farnese Atlas) or images which incorporate the globe (as on coins); sundials (which can signify the ephemeral character of human life); astrological apparatus on gems (a continuation of Heilen's and Greenbaum's discussion); and representations of the gods, planets, and weekdays (extending Lehoux's discussion).

The last chapter, by Bernhard Weisser, looks at the imagery of time and the cosmos in the Roman empire through a numismatic lens. The coins from the exhibition form the focus of his discussion; and, within that corpus, the image of the Capricorn is used as a hook on which to hang a wide-ranging discussion of its symbolic value. The zodiacal sign was famously adopted as a personal symbol by Augustus after his horoscope had been delivered to him by the astrologer Theogenes, and Weisser notes the growing support for the view that Augustus may have chosen this sign because it was the sign under which he was conceived, rather than the one under which he was born (which should be Libra). Other symbols discussed include the *sidus Iulium*, the comet which appeared during the funeral games for Julius Caesar held by Octavian (the future Augustus), and the zodiac.[5]

[5] Ramsey and Licht 1997 should still be noted as a major discussion on this phenomenon, particularly with regard to the astronomical context.

The Exhibition Checklist of all objects displayed follows this final chapter, and includes details of material, scale, provenance, and date. A generally up-to-date bibliography of sources in a variety of languages and a list of photography and drawing credits round off the book.

It is not uncommon for multi-authored books to be criticized for the lack of communication between the various chapters. This is not the case with this book. Not only does Jones in his introduction neatly integrate all the chapters together around the central theme of the exhibition, but each chapter references others that have relevance to its themes.

This is an outstanding catalog for what must have been visually an outstanding exhibition. The editor and his authors are to be congratulated for accessible analyses and discussions. The staff of ISAW and of Princeton University Press also deserve high praise for the quality of the publication: the photographic illustrations are uniformly of a very high standard. This book is a pleasure to see and read.

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Ptolemy's Philosophy: Mathematics as a Way of Life by Jacqueline Feke

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Jacqueline Feke's book presents the results of her efforts to elucidate Claudius Ptolemy's philosophical system. That Ptolemy conceived his mathematical studies as forming part of a broader investigation is especially clear in the elaborate preface of the *Almagest*, in which he defends the thesis that mathematics is the only non-conjectural part of philosophy. For Ptolemy, only with mathematics can we advance in physics and theology, the two other branches of theoretical philosophy in the classification of knowledge that he proposes; and, furthermore, only mathematics helps us approach the divine. Thus, even if at the beginning of this preface he posits that ethics is independent of theoretical philosophy, Ptolemy ends up making it dependent upon it. As Feke notes [78], this is typical of several philosophical passages in Ptolemy's works, in which his writing takes the form of a serious, ongoing philosophical investigation, as in his discussion of the constitution of body and soul in *On the Criterion and the Commanding Faculty*. We would perhaps expect that short philosophical excursions by a mathematician adopt a more expositional, handbook tone; but they turn out to be original and valuable records that are worth studying for his thinking process, the vivid style of which (I dare propose) demonstrates Ptolemy's admiration for Plato's dialogues and of Aristotle's treatises.[1]

Ptolemy's philosophy is mainly to be connected with Middle Platonist trends that appropriated key concepts from Aristotle's esoteric works, which were made available sometime during the first century BC, the time of Androni-

[1] The two authorities seem to be alluded to in the preface of the *Almagest*: this is obvious for Aristotle, who is cited for the classification of the theoretical parts of philosophy, but a typical form of Socratic criticism of other philosophers in Plato's dialogues is probably also in Ptolemy's mind at the very beginning, when he uses the expression 'the true philosophers' («οἱ γνησίως φιλοσοφήσαντες»). Cf., e.g., *Resp.* 473d οἱ βασιλῆς τε νῦν λεγόμενοι καὶ δυνάσται φιλοσοφήσωσι γνησίως τε καὶ ἱκανῶς.

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cus. Like other technical authors of his time, Ptolemy found a philosophical justification and setting for his lifelong mathematical pursuits; but his case is especially remarkable for being extremely sophisticated and without clear precedents in the history of mathematics. Unlike the case of medicine—the obvious comparable figure is Galen—there does not seem to have existed a tradition of mathematical works ingrained to a similar degree in any philosophical system, except perhaps in the case of harmonics, which, probably not coincidentally, Ptolemy studied at the beginning of his career. It should, then, not be surprising that the *Harmonics* is, among Ptolemy's mathematical works, the one in which we find a deeper engagement with philosophical issues, and that his only entirely philosophical text (in the traditional sense, that is, without mathematics), the above-mentioned essay *On the Criterion*, deals with epistemological topics that play an important role in the *Harmonics* (for which reason it is also ascribed to this first stage of Ptolemy's career).

Ptolemy thus subverting at once the propaedeutic role assigned to mathematics in Platonic thinking and the lesser importance attached to it in the Aristotelian hierarchy of the parts of philosophy, presents himself as a true philosopher, the creator and principal adherent of his own mathematical-philosophical system. That the concept of this global philosophical-mathematical system was ever influential is doubtful, since we do not hear of any contemporary followers, and since Ptolemy's influence in later authors seems restricted to the individual disciplines and to the more technical aspects of his works, be it the astronomical models of the *Almagest* and the *Handy Tables*, versions of which began to circulate in third-century papyri and ultimately replaced Babylonian-style astronomical tables in astrological practice, or the astrological doctrines themselves that are masterfully synthesized in the *Tetrabiblos*.[2] Again, the only strictly philosophical section (in the traditional sense) of Ptolemy's works which seems to have received attention in antiquity is the first part of the *Harmonics*, which was studied at length by Porphyry in his commentary on that work. But, as mentioned above, there was a long tradition going back to Archytas that discusses the criteria in harmonics. It is precisely the relation between Ptolemy's tenets and those of his predecessors in harmonics that Porphyry explores in his commentary.

After all, mathematicians were very few in antiquity, and perhaps Ptolemy's all-encompassing philosophical project was meaningful only in his own time. Thus, unlike Galen, who often portrays himself as surrounded by fol-

[2] *Pace* Feke, who in the conclusion [205–207] is more optimistic about the possible influence of Ptolemy's philosophy in antiquity and even in modern times.

lowers and peers who attend his demonstrations, who has in mind a myriad of dedicatees and students with different interests when writing his works, and who writes treatises on logical reasoning for his medical students, we hear only of one single reader of Ptolemy's works, the obscure Syrus, about whom we can deduce only that he was interested solely in astronomical (including astrological) matters, given that he appears as the dedicatee of Ptolemy's works devoted to these topics.[3] Such mathematical loneliness was of course not exclusive of Ptolemy. Consider the example of Archimedes, who bitterly regrets the death of his peer Conon in the preface of his *On the Sphere and the Cylinder*, probably because Conon was one of the few people in his time who was interested in, and could understand, his work.[4]

Feke's study derives from her PhD thesis [2009]; in fact, two and a half of the eight chapters in her book (the second part of chapter 3, and chapters 4 and 7) are but slight modifications (with due acknowledgement) from three published articles deriving from the same dissertation, which was supervised by the historian of ancient Greek astronomy Alexander Jones.

Astronomy has always been the major gateway to Ptolemy. Following the profound and encyclopedic work of Otto Neugebauer,[5] Jones has been a major contributor to this field [cf., e.g., Jones 1999]. Perhaps next in interest in the last decades has been Ptolemy's *Geography*, which has also been studied by Berggren and Jones [2000], but which has received more attention in the Berlin-based study-group responsible for the most recent edition of this work (which has probably reached a smaller audience due to the use of German) [see Stückelberger and Graßhoff 2017]. In parallel with Jones' work on astronomy, study of ancient Greek music has been revived by a handful of specialists, most importantly by Andrew Barker, whose clear and didactic annotated translation of virtually all ancient Greek texts on music theory has done an invaluable service in attracting people to the field.[6] Barker [2000] is also particularly relevant here because he has contributed

3 For Galen's diverse readership, see Johnson 2010, 85–87.

4 Archimedes, *Sph. et cyl.* 1 pref. ὤφειλε μὲν οὖν Κόνωνος ἔτι ζῶντος ἐκδίδοσθαι ταῦτα. For a survey of the number of mathematicians in the ancient Greek and Roman world, see Netz 1999, ch. 7.

5 I am referring to the greatly influential Neugebauer 1975 and Neugebauer and van Hoesen 1987.

6 Most of the ancient texts are included in Barker 1989. In addition, Porphyry's commentary has been recently reedited (without a new inspection of the manuscripts), translated, and annotated in Barker 2015. Cf. my review in Tolsa 2016a.

a monograph to examining Ptolemy's scientific method in the *Harmonics* [cf. Creese 2010].

As Feke recognizes [2], there have been very few scholars who have been interested in Ptolemy's philosophy for its own sake, that is, without being interested primarily in one of the particular mathematical fields in which Ptolemy was active—indeed, it is difficult to say where his philosophy ends and where his mathematics begins, for, according to him, mathematics is *the* main part of philosophy. A complete study of Ptolemy's philosophy should, therefore, be a study of the whole Ptolemaic corpus, an obviously titanic task out of the reach of a single individual in a relatively short interval. Thus, the title of the precursor to Feke's book, Liba Taub's *The Natural Philosophical and Ethical Foundations of Ptolemy's Astronomy* [1993] is, strictly speaking, a more apt description of the content of this kind of study, if perhaps a less catchy one. To find another longer piece on Ptolemy's philosophy *per se* we have to go back to Franz Boll [1894]. Nevertheless, Boll's study was to a significant degree concerned with defending the authenticity of the ascription to Ptolemy of the philosophical essay *On the Criterion*, and, especially, of the astrological treatise, the *Tetrabiblos*, and accordingly devoted more effort to underlining the coincidences between the philosophical tenets in the various works than in explaining them. Neither Taub nor Boll reviewed Ptolemy's *Harmonics*—I suspect Barker's work has been responsible for making this step possible—which is what leads to Feke's claim that 'this monograph is the first ever reconstruction and intellectual history of Ptolemy's general philosophical system' [2].

From a more general perspective, there are two scholarly fields which have seen a significant development in the last times, and which are relevant to research on Ptolemy's philosophy. One of them, signaled by Feke in her introduction [3–4], is the revitalized research on the philosophical milieu of early Roman times, especially the authors labelled as Middle Platonists. In particular, Feke points out clear affinities between Ptolemy and Alcinous' handbook (on the divisions of theoretical philosophy [30]), and with Albinus' introduction to Plato (on becoming similar to god [69]). Also noteworthy is the new interest in the work of the first Aristotelian commentators, Adrastus and Aspasius (second century AD), from which only parts of the latter's commentary on the *Nicomachean Ethics* are extant, and in which Feke finds an interesting parallel to Ptolemy's discussion of the possible dependency of the practical part of philosophy on the theoretical [54–55].

Finally, Ptolemy's output can be fruitfully compared with that of his scientific peers, though Feke does not go into this. Recently, there have been great efforts in the scholarly community to understanding how knowledge was created, shaped, and presented in the early Roman empire. Again, Galen is the evident parallel for Ptolemy because of the deep philosophical entrenchment of his medical project.[7] But analysis of the work of other scientific authors such as Vitruvius, Hero of Alexandria, Theon of Smyrna, Nicomachus of Gerasa, or Plutarch (to name just a few) can also contribute to the appropriate contextualization of Ptolemy's endeavors.[8] Of course, this is an immense topic, and the individual researcher needs to choose where to set limits. Feke has decided to study all of Ptolemy's 'strictly' philosophical passages, but it would also be possible, and even desirable, to explore a particular facet of Ptolemy's project in relation with similar practices among his peers.

In my view, whereas Feke's study is highly valuable, the need for further contextualization should be emphasized, since we otherwise run the risk of isolating Ptolemy from his contemporaries. Feke does a great job of making sense of Ptolemy's system internally, surveying everything in Ptolemy that can be related to 'straight' philosophical texts in and around his time—including the preface of the *Almagest* [ch. 2–4], harmonic theory [ch. 5–6], psychology [ch. 7], astrology and cosmology [ch. 8)—but we are lacking a context explaining why Ptolemy presented his mathematics in this highly harmonized philosophical system. In this sense, not only comparison with other scientists is needed, but also with other intellectuals who used philosophical doctrines as a ready toolbox to present their special knowledge. I am thinking, for example, of Philo of Alexandria, who, a little more than a century before Ptolemy, explained the Bible using a mainly Platonic framework. My own research on Ptolemy, roughly parallel with Feke's, has shown that some elements of Ptolemy's system go back to such Alexandrian philosophers of the first century BC who made an impact on Philo as Eudorus and Aristo.[9]

This adds a geographical dimension that is relevant to Ptolemy, and which is totally absent in Feke's book. Philosophical ideas from the Hellenistic schools seem to have been transferred to the Alexandrian milieu only after Hellenistic times, where they were newly combined without the influence of the philosophical schools. It is perhaps not by coincidence that Alexandria

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7 See, e.g., the essays collected in Gill, Whitmarsh, and Wilkins 2009.

8 See, e.g., the collected papers in König and Whitmarsh 2007, Taub and Doody 2009, and König and Woolf 2017.

9 See the parallels with Plutarch, probably deriving from Eudorus, in Tolsa 2014. For the comparison of the criterion with a law court and the parallel with Aristo of Alexandria (famous for leaving the Academy for the Peripatos], see Tolsa 2016b.

was the seat of Potamo's eclectic sect of philosophy.[10] Admittedly, this is a very difficult topic, mainly due to the almost complete obliteration of the relevant sources. But from what survives, it has been established that, in the metaphysics of Alexandrian Middle Platonists such as Eudorus, mathematical objects played a new, mediating role between the physical world and the forms [see Bonazzi 2011]. This may have constituted the basis of Ptolemy's subversive claim that mathematics surpasses, and at the same time contributes to, the other branches of philosophy, thanks both to its non-conjectural epistemological status and to its mediating position. Such views had obviously to do with the revival of the *Timaeus* as the major Platonic text explaining the new globalized world, beginning with Stoics like Posidonius, interested in underlining the great interconnections and *mirabilia* of this new *oikoumene*.[11]

This leads to another interesting topic of early Roman intellectual history, namely, the packaging of knowledge in disciplines. Ptolemy synthesizes all mathematical astronomy in his *Almagest*—which he accordingly simply calls the *Astronomical Composition* (μαθηματικὴ σύνταξις)—all astrological knowledge in the *Tetrabiblos*, and the geographical coordinates of the whole inhabited world, as known by the Romans, in his geographical treatise. Such an encyclopedic, mathematical project, the result of combining Ptolemy's genius with that of all his predecessors in one book per discipline, is a typical Roman development. Critical collection of knowledge inherited from the past, combined with new insights and great synthesizing ability, are the essential ingredients of many Roman intellectual projects that prefigure the medieval curriculum of disciplines. The mathematical sciences of Plato's *Republic* 7, which finally came to form the quadrivium, were already the way in which Theon of Smyrna and Nicomachus of Gerasa organized their work; and we also hear of Varro's classification of the knowledges in nine disciplines [Vitruvius, *De arch.* 7.pr.14]. Ptolemy's discussion of the relation between astronomy and harmonics in *Harm.* 3.3 is illustrative of how conscious he is about such classifications; significantly enough, he adapts a traditional analogy—he calls astronomy and harmonics cousinly rather than sister sciences—that goes back to Archytas, and to which Nicomachus also recurs when presenting his Platonic division of knowledge [*De arith.* 3].

[10] Cf. the useful review of the main philosophical trends in early Roman Alexandria in Hatzimichali 2011, ch. 2.

[11] Regarding this Posidonian connection, it is noteworthy that both Eudorus and Aristo wrote a book on the source of the Nile flood, according to Strabo, *Geog.* 17.1.5.

It seems to me, however, that Feke's analysis lacks awareness of such passages that create a frame-story, since she wonders at length [131–140] about the fact that, whereas, for Ptolemy, both harmonics and astronomy share *a priori* the same status as incontrovertible knowledge, he ends up admitting the reality that complete agreement of the astronomical models with the observations is impossible [e.g. *Alm*. 3.1]. Feke asks herself why it is that, if Ptolemy makes astronomy dependent on geometry, he bothers to quantify his geometrical models, which makes the disagreement perceptible. Both astronomy and harmonics had long been independent sciences, and, although their similarities made them comparable for Archytas, Plato, and Ptolemy, they had different epistemologies. For astronomers of Ptolemy's time, it was a mandate to provide astrologers with the means of assessing the solar, lunar, and planetary longitudes; and Ptolemy was, as we know, greatly successful at this, even if, of course, the resulting numbers did not completely agree with the observations. Unlike in the case of astronomy, music is human-created, and small changes can be forced into the musical scales in order to make them fit a predefined pattern. This is why in *Harm*. 2.1, where Ptolemy 'proves' that real music as performed by a real citharode fits the mathematical ratios that he has established for his tetrachords in the previous book, he can stipulate that all intervals heard must be made of epimoric ratios, i.e., ratios of the form $(n+1):n$, which makes the job much easier.[12]

Nevertheless, Feke clarifies for us Ptolemy's quite idiosyncratic ordering of knowledge, showing that his Middle Platonic/Aristotelian division of philosophy in the preface of the *Almagest* can serve to illustrate many features of his work. Feke is particularly good at unpacking Ptolemy's dense language in his exposition of these divisions, and at explaining how sections or major parts of his work indeed consist in his announced application of mathematics to physics, be it that of harmonics to psychology (Ptolemy conceives the soul as material) and cosmology (the heavenly substance is aether), or that of astronomy to astrology and cosmology. However, Feke contends, this nice picture does not work for *On the Criterion* because it contains no mathematics [6, 145]. Here I remain unconvinced by her arguments that the essay does not treat mathematics because it was written before Ptolemy had conceived his global project. It may well be the case, and it seems indeed probable, that this text was written before the *Harmonics* and all other pieces; but I doubt that this is the reason why it had no mathematics. The criterion of

[12] Cf. on this important chapter and the curious transformations it suffers in Porphyry's commentary, Tolsa 2017a.

truth was for Ptolemy an epistemological prerequisite for his investigation in mathematical harmonics, and not the other way around. I would be at a loss to image what kind of mathematics could have been included in the text, if not examples, but the *Harmonics* already provides the best possible example of application of the criterion. The manual of Alcinous is again illustrative, since it presents the topic of the criterion in a separate chapter [4], even if philosophy has been previously divided into the practical and the theoretical [3] in almost the same way as Ptolemy, without including the criterion of truth. To compare with Galen: the criterion was important to the study of harmonics in a similar way as logic was for the doctor who wanted to make deductions correctly, and that is why Galen wrote treatises on logic (without, of course, applying medicine to logic).[13] Therefore, I would suggest that the criterion functions in Ptolemy's system as proto-mathematics. This would explain that the latter part of the essay deals with psychology (i.e., here Ptolemy would also apply mathematics to physics).

As for the application of mathematics to the other branch of theoretical philosophy, theology according to the preface of the *Almagest*, it is not clear whether we can find any tangible example in Ptolemy's works. Of course, Ptolemy implies that the very study of astronomy makes us followers of divine beauty, habituating or disposing us to the same state of soul, and this by itself could presuppose a contribution to theology. I would, however, add that Ptolemy was self-consciously designing his works to be beautiful, well-proportioned objects, and that they could in this way be conceived as offerings to the gods (and, therefore, as a form of theology). It is well known that the concepts of beauty and proportion are highly related in Platonism, as well as in Ptolemy's own thought [cf. *Harm*. 1.3.4]. The Canobic inscription, which was dedicated to a 'savior god' who preserves what is written, is divided into two sections of a relative length similar to that of the two main sections of the *Harmonics*. In both cases, the last section is devoted to applying harmonic ratios to the physical world: in the case of the *Harmonics* to the human soul and the heavens, and in the case of the inscription only to the heavens. *On the Criterion* also presents a similar division. Through textual analysis (especially of the *Harmonics*), it is possible to relate this rhetorical structure to the two-part discourse of *Timaeus* on the creation and the nature of the cosmos in Plato's dialogue, the second part beginning with the introduction of the receptacle (48b προσήκουσαν ἑτέραν ἀρχὴν)

[13] There are some hints at the Aristotelian categories in the text *On the Criterion*: cf. again Tolsa 2016b.

[cf. Tolsa 2014]. It is distinctive of Timaeus' speech that he calls upon the gods at the two beginnings, and also in opening the follow-up dialogue, the *Critias*, appealing as Ptolemy does, to the divine savior capacity granting success to the intellectual project.[14] My guess is that such proportionate division, common to these three works, is meant to make the text beautiful and thus, in a certain sense, agreeable to the gods, something which would have been at least desirable in the case of the Canobic inscription, itself an object dedicated to a deity.

Another kind of elaborate presentation can be seen in the *Almagest* and in the *Geography*, in which long catalogues (occupying the most part of the work in the latter case) appear in both cases carefully positioned toward the middle of the whole text, as if in a circular structure, perhaps mimicking the circular nature of the object of study. Again, Ptolemy was not alone here, since several authors adopted analogous textual strategies to underline the divine character of their works: to mention just a couple of examples, Vitruvius divided his architectural treatise into 10 books, which is surely not just a coincidence with the fact that this number was considered perfect in antiquity, as mentioned by himself [*De arch*. 3.1.8]; and Galen compares his master work, *De usu partium*, to an epode at the very end of the text,[15] explaining that this part of lyric poems was addressed to the gods (ὑμνοῦντες τοὺς θεούς).

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[14] Plato, *Tim.* 27c, 48d; *Critias* 106a–b. On the significance of invoking the deity in the *Timaeus* and the *Almagest*, see Tolsa 2017b.

[15] Kuhn 4.365 ὁ λόγος οὗτος ὥσπερ ἀγαθός τις ἐπῳδὸς ἐξηγεῖται.

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