

I. The Greek and Near Eastern Traditions

The Ancient Ptolemy

Alexander JONES

1. Introduction

Before the medieval Ptolemy — Ptolemaeus Arabus and Ptolemaeus Latinus, not to forget Ptolemaeus Byzantinus — was the ancient Ptolemy. Or rather, there were ancient Ptolemies, starting with a man who composed a wide range of scientific texts and tables in Antonine Roman Egypt, and trailing after him, the shadowy Ptolemies who were the images of this author as he was known to people of the four remaining centuries of antiquity following his own career. For within a few decades of his time, a process of disintegration of Ptolemy's unity had set in, because even his earliest readers, users, and commentators were unable to mirror the breadth of his scientific interests or grasp the philosophical and didactic agenda that shaped his approach across his individual fields of study; even today, historians tend to specialize according to disciplines whose boundaries cut across Ptolemy's œuvre. My object in the present essay is to explore the extent to which we can know the original, in-the-round Ptolemy, and to identify some aspects of his thought that become more apparent from consideration of the full breadth of his work and that might affect how we receive the specifically astronomical and astrological works that constitute the core of the 'Ptolemaeus Arabus et Latinus' project.

The crucial limitation to our knowledge of the historical Ptolemy is the lack of useful information independent of his writings. This should come as no surprise to any student of antiquity, who knows how rare it is that a Greco-Roman scientific author whose works survived into the medieval manuscript tradition was also a personality traceable in references in literature or in archeologically recovered artifacts and documents from his own time. The case of Archimedes, in which we have on the one hand a corpus of technical mathematical treatises preserved through three early minuscule Byzantine codices and on the other various anecdotes and legends pertaining to his life, is not really an exception, since the biographical reports are only known to us through such later writers as Cicero and Plutarch. A more instructive comparand for Ptolemy is his contemporary Galen. The immense Galenic corpus contains enough autobiographical material for us to reconstruct a detailed if *parti pris* life of a figure whom Bowersock memorably and accurately describes as a lion of

Roman society, yet contemporary and near-contemporary allusions to him are few and scarcely reflect the stature and strong personality conveyed by Galen's self-references.¹ Ptolemy's virtues walked a narrower round, for second-century Alexandria was a provincial intellectual center compared to Galen's Rome — and besides, by the standards of the so-called Second Sophistic movement that served as the gaudy public face of Antonine intellectual life, Ptolemy was an introvert.² Perhaps Galen himself came into contact with Ptolemy during his youthful sojourn in Alexandria in the mid-150s (around when Ptolemy published the *Almagest*), and perhaps many years later he included Ptolemy in a list of important but under-read astronomical authors in his commentary on *Airs, Waters, Places* — though the circumstance that in the extant Arabic translation of Galen's commentary he appears as 'Ptolemy king of Egypt' invites suspicion that his presence here is the result of a medieval interpolation.³ Otherwise any impact Ptolemy the man had on his contemporaries is invisible to us. Effectively, anything that we can know of him has to come from his writings.

2. Establishing the Ptolemaic corpus

How sure are we what were his writings were? The starting point, of course, is the presence of Ptolemy's name at the header or footer of a text as preserved in the extant manuscripts. As we learn from Galen's *On My Own Books*, however, an author — even of technical literature, for which the market was presumably somewhat restricted — could have the disconcerting experience of finding his own name attached fraudulently to a bookseller's wares, to say nothing of false attributions from later times. And unlike Galen, Ptolemy left no catalogue of his literary production.

If we take the *Almagest* as *par excellence* the authentic Ptolemaic text, we can say of several others ascribed to Ptolemy that they must either be his or have been intentionally falsified so as to appear to be his, since they have either an opening address to Syros, the dedicatee of the *Almagest*, or an explicit back-reference to the *Almagest*, or both:

¹ Moraux, *Galien de Pergame*; Bowersock, *Greek Sophists*, p. 66; Nutton, 'Galen in the Eyes'.

² It has been vigorously disputed whether Galen qualifies as a figure of the Second Sophistic, e.g. Bowersock, *Greek Sophists*, pp. 59–75; Brunt, 'The Bubble', esp. pp. 43–46; von Staden, 'Galen'. No one, to my knowledge, has associated Ptolemy with the movement.

³ Toomer, 'Galen on the Astronomers', esp. p. 204; Strohmaier, 'Galen's Not Uncritical Commentary'.

<i>Work</i>	<i>Primary language of preservation</i>	<i>Address to Syros</i>	<i>Reference to Almagest</i>
<i>Planetary Hypotheses</i>	Greek (parts Arabic)	Yes	Yes
<i>Arr. and Comp. Handy Tables</i>	Greek	Yes	Yes
<i>Tetrabiblos</i>	Greek	Yes	Yes
<i>Karpos (Centiloquium)</i>	Greek/Arabic/Latin	Yes	No
<i>Geography</i>	Greek	No	Yes
<i>Analemma</i>	Latin (parts Greek)	Yes	No
<i>Planispherium</i>	Arabic/Latin	Yes	Yes

Table 1. Authorship evidence from dedications and cross-references

The remaining texts ascribed to Ptolemy in the manuscripts and that recent scholarship has treated as plausible contenders for authenticity despite the absence of reference to the *Almagest* or dedication to Syros are the *Phaseis*, *Canobic Inscription*, *Criterion*, *Harmonics*, and *Optics*.

On the other hand, there exist many texts that, though ascribed to Ptolemy in the manuscripts, it is unlikely anyone would now make a case for as his work. In Greek, we have the *Karpos* of course, though it has been maintained that the Greek version is a translation of an Arabic original, and *Musica*, a short text partly adapted from the final cosmic-harmonies section of the Canobic Inscription but otherwise devoted to musical terminology unrelated to Ptolemy's *Harmonics*.⁴ *Claudii Ptolomei [sic] de Speculis* is William of Moerbeke's Latin translation of a short treatise on catoptrics that was certainly present in Greek in one of the two lost codices from which William translated several works of Archimedes and Eutocius as well as Ptolemy's (authentic) *Analemma*; the attribution has universally been rejected since the early nineteenth century, and modern editions present it either as a work of Heron of Alexandria or as anonymous.⁵ Additionally, numerous manifestly spurious astrological and astronomical texts are extant in Latin or Arabic under Ptolemy's name, for which there is no evidence of Greek originals.⁶

The foregoing discussion has not touched on the *Handy Tables*. In fact what we now understand to be Ptolemy's *Handy Tables* is a modern recon-

⁴ On the *Karpos* and the Arabic and Latin traditions of the *Centiloquium* see Juste, 'Pseudo-Ptolemy, *Centiloquium*' and the article by Jean-Patrice Boudet in this volume. *Musica* is edited in von Jan, *Musici Scriptores*, pp. 411–20, and discussed by Swerdlow, 'Ptolemy's Harmonics', esp. pp. 176–78.

⁵ Jones, 'Pseudo-Ptolemy *De Speculis*'. The manuscript in which William found the text is listed in the 1311 inventory of the papal Greek manuscripts as 'undecim quaternos... in quibus est liber Tholomei de resumptione [i.e. the *Analemma*], perspectiua ipsius [i.e. the *De Speculis*], perspectiua Euclidis, et quedam figure Arcimenedis [sic]'; thus the ascription to Ptolemy was already in this manuscript, not a guess of William's. See Jones, 'William of Moerbeke', esp. p. 19.

⁶ For Arabic pseudepigrapha see Sezgin, *Geschichte*, vol. VII, pp. 46–47; for Latin, <https://ptolemaeus.badw.de/works/>.

struction obtained as a subset of collections of astronomical tables preserved in numerous Byzantine manuscripts, in particular four dating from the ninth and tenth centuries, the selection being guided chiefly by Ptolemy's *Arrangement and Composition of the Handy Tables* and Theon's two commentaries on the *Handy Tables*.⁷ Most of the manuscripts in question present the tables anonymously, and the occasional appearance of Ptolemy's name in association with them (which of course would apply on the face of it to all tables in the collection, not just the subset modern scholarship endorses) does not constitute a robust ascription.⁸

Since modern philological methods began to be systematically applied to ancient scientific texts, the works in the Ptolemaic canon whose authenticity has been the subject of serious discussion include the *Tetrabiblos*, the *Karpos* (*Centiloquium*), the *Criterion*, the *Canobic Inscription*, and the *Optics*. Following Boll's 1894 'Studien über Claudius Ptolemäus', in which he argued extensively for the authenticity of the *Tetrabiblos* and more briefly for the spuriousness of the *Karpos*, the status of those two works has effectively been settled.⁹ Concerning the *Criterion*, however, Boll writes:¹⁰

Dass die Schrift nur dem Mathematiker Claudius Ptolemäus gehören kann, bedarf keines Beweises: Anschauung und Stil zeigen dies selbst dem flüchtigsten Blick.

But the very fact that he felt the need to make this assertion implies that the question of authorship was not entirely straightforward, and in this instance Boll's authority failed to establish a consensus.¹¹ Any doubts about the *Canobic Inscription* vanished following Hamilton's demonstration that a certain passage in the *Almagest* (4.9) alluding to parts of Ptolemy's lunar and planetary the-

⁷ Tihon, 'Les Tables Faciles'.

⁸ For manuscripts identifying their contents as 'Ptolemy's *Handy Tables*' (Πτολεμαίου πρόχειροι κανόνες) see Heiberg, *Opera astronomica minora*, pp. cxc–cciii. None of the earliest copies has such a heading, and in those that do, it is likely to be a Byzantine scholar's conjecture.

⁹ Boll, 'Studien', pp. 111–80 (*Tetrabiblos*) and 180–81 (*Karpos*).

¹⁰ Boll, 'Studien', p. 77.

¹¹ Rose, *De Aristotelis librorum*, p. 45 had already baldly denied Ptolemy's authorship of the *Criterion* ('ad astronomum certe cui adscribit editor [*scil.* Boulliau] nihil pertinentem'). More recent dissenters include Toomer, 'Ptolemy', esp. p. 201 ('There is nothing in its contents conflicting with Ptolemy's general philosophical position, but the style bears little resemblance to his other works; and the ascription, while generally accepted, seems dubious'); Taub, *Ptolemy's Universe*, p. 9 ('a work whose attribution to Ptolemy has been questioned'); and Swerdlow, 'Ptolemy's Harmonics', pp. 179–80 ('Concerning the short work on epistemology attributed to Ptolemy, *On the Criterion*, I have nothing to say except to doubt its authenticity, or at least its pertinence to the subjects considered here... It contains not a single reference to the subjects of Ptolemy's other works, *all* in the mathematical sciences, and parallels that have been drawn with the *Harmonics* seem to me vague.').

ories that he had revised refer in fact to the parameters in the inscription.¹² Though the *Optics* has been regarded as authentic by most scholars from the nineteenth century to the present, Rome expressed doubts while more recently Knorr contended that the ascription to Ptolemy was sufficiently insecure that it would be preferable to take as a working hypothesis that it was by a different author.¹³

Arguments for or against the authenticity of writings attributed to Ptolemy have rested chiefly on three types of evidence: comparison of thought with other works accepted to be Ptolemy's, comparison of style, and testimony of later authors. Boll's discussion of the *Tetrabiblos* applies all three, and the abundance and (in large part) the quality of the arguments render his case for Ptolemy's authorship thoroughly persuasive. The *Criterion's* authorship is supported by no ancient testimony beyond the attribution in the work's manuscript tradition, and Boll backs up his assertion, quoted above, that Ptolemy's authorship is obvious merely by referring to arguments offered by Boulliau in his 1644 *editio princeps*, which are in reality not particularly impressive. The *Optics* is transmitted minus its entire first book, the conclusion of the fifth, and perhaps further books if there were any, and only in an intermittently incoherent Latin translation of an Arabic translation, such that most stylistic traits of the original Greek text can scarcely be discerned. The testimonia do not correspond to any passages in the extant work, leaving the question open whether they refer to material in the lost Book 1 or to another work entirely. Arguments regarding the *Optics's* authorship have thus operated primarily at the level of thought, which is the most subjective of the criteria, especially considering that the subject matter of the *Optics* has little overlap with the accepted writings of Ptolemy.

Stylistic arguments that are adduced in favor of the common authorship of two or more texts often depend on similarities in vocabulary and idiom, and care must be taken to ensure that the presence of such shared expressions is truly significant. Boll's long list of stylistic features shared by the *Tetrabiblos* and by Ptolemy's acknowledged works includes some that are indeed specially characteristic of Ptolemy as well as others that are not. An example of the latter is the qualifying phrase οὐ τὸ τυχόν (in whatever gender and case is appropriate), meaning 'not just any,' or effectively 'significant'; Ptolemy is fond of it,

¹² Hamilton et al., 'The Canobic Inscription'.

¹³ Rome, 'Notes sur les passages', esp. p. 36; Knorr, 'Archimedes', esp. pp. 96–104. (Knorr offers as a potential alternative author Ptolemy's approximate contemporary, the peripatetic Sosigenes.) Ptolemy's authorship of the *Optics* had previously been put in question by Caussin de Perceval, 'Mémoire sur l'*Optique*', esp. pp. 26–29. See also now Siebert, *Die ptolemäische Optik* for an extended argument that the *Optics* is a work from late antiquity.

but it turns up about as frequently in several other authors, including Athenaeus, Galen, and Lucian.

The availability of a near-comprehensive searchable corpus of ancient Greek texts preserved through the medieval manuscript tradition, the *Thesaurus Linguae Graecae* (TLG), has made it possible to identify an unexpected trait of Ptolemy's writing that allows a secure test of his authorship applicable to all the texts preserved in Greek that are attributed to him and that include a significant quantity of prose, that is, everything but the *Canobic Inscription* and the *Handy Tables*. Ptolemy's style is, by the standards of his time, not florid, but it is not exactly plain either. In particular, certain words and phrases that he used across multiple works — not specialized technical expressions connected with his subject matter — turn out to be otherwise so rare that, in the TLG corpus, they occur in no other author before the fourth century, or in extremely few, and these are often authors who wrote under the strong influence of Ptolemy's writings.

Consider for example the opening sentence of *Almagest* Book 2, a typical example of the transitional passages in which Ptolemy sums up retrospectively the contents of the preceding part of a work before announcing the topic to follow:

διεξεληθόντες ἐν τῷ πρώτῳ τῆς συντάξεως τά τε περὶ τῆς τῶν ὕλων σχέσεως κατὰ τὸ κεφαλαῖῳδες ὀφείλοντα προληφθῆναι, καὶ ὅσα ἂν τις τῶν ἐπ' ὀρθῆς τῆς σφαιρας χρῆσιμα πρὸς τὴν τῶν ὑποκειμένων θεωρίαν ἡγήσασατο, πειρασόμεθα κατὰ τὸ ἐξῆς...

Having in the first [book] of the composition gone through *in summary manner* the matters concerning the arrangement of the universe that ought to be assumed beforehand, and all the matters in the *sphaera recta* situation that one would suppose to be useful for the investigation of the subject at hand, we shall next try...

The phrase κατὰ τὸ κεφαλαῖῳδες, here translated 'in summary manner', turns up also in the *Tetrabiblos* in the retrospective part of four transitional passages (1.3.20, 2.4.1, 2.14.12, 3.14.9) as well as in one passage (3.4.4) that lists a series of ensuing topics unprelaced by a retrospection. For example, the transition in 2.4.1 is as follows:

αἱ μὲν οὖν συνοικειώσεις τῶν τε ἀστέρων καὶ τῶν δωδεκατημορίων πρὸς τὰ κατὰ μέρος ἔθνη καὶ τὰ ὡς ἐπίπαν αὐτῶν ἰδιώματα κατὰ τὸ κεφαλαῖῳδες τοῦτον ἡμῶν ὑποτετυπώσθωσαν τὸν τρόπον. ἐκθησόμεθα δὲ καὶ...

Let the shared affinities of the stars [i.e. the Sun, Moon, and planets] and the zodiacal signs with respect to the individual peoples and their overall characteristics have been sketched by us *in summary manner* in this way. We shall also set out...

In the *Criterion* it occurs in the prospective part of a transitional passage (15.1):

τούτων δὲ οὕτως ἐφωδευμένων, ὅτι μὲν ἡγεμονικὸν γίνεται τοῦ σώματος, ἐν ᾧ τὸ ἡγεμονικὸν τῆς ψυχῆς, οὐδὲ εἷς ἂν ἀπορέσειεν, εἰ δ' αὐτὸ τὸ ἡγεμονικὸν οὕτως

ἀπλῶς ληπτέον καὶ οὐχ ὡς τῶν πρὸς τι ὄν, ὡδὶ πως κατὰ τὸ κεφαλαϊῶδες διοριστέον.

Now that these things have been treated methodically, no one would have difficulty with the fact that there is a *hégemonikon* of the body, in which is the *hégemonikon* of the soul, but if this very *hégemonikon* is to be taken thus absolutely and not as relative to something, one ought to draw distinctions *in a summary manner* in something like the following way.

What makes this instance of the phrase in the *Criterion* significant is the fact that, outside of the *Almagest* and *Tetrabiblos*, it is only attested in authors later than Ptolemy who were heavily influenced by him. In the *TLG* corpus it occurs only in two passages of the astrologer Hephaestion of Thebes (1.20 = Epitome IV 15, and 1.25) which respectively are close paraphrases of the passages from *Tetrabiblos* 2.4 and 2.14 cited above, and in section 6 of the anonymous ‘Geographiae expositio compendiaría’ (Müller, *Geographi Graeci Minores* 2.494–509), an opusculum of uncertain but definitely late date for which Ptolemy’s *Geography* was a major source.¹⁴

The transitional passage from *Tetrabiblos* 2.4 quoted above also contains the perfect passive imperative verb ὑποτετυπώσθωσαν, following the manuscript reading adopted by Hübner and by Robbins, or ὑποτετυπώσθω following the reading preferred by Boll and Boer (either form is grammatically admissible). This perfect passive imperative of ὑποτυπώω turns out to be another special word for Ptolemy, occurring in the recapitulative parts of transitional passages in the *Tetrabiblos* (2.4 as already mentioned), the *Harmonics* (1.4, 2.3, 2.11, and 3.4), and the *Geography* (1.2.1, 1.18.1, and 2.1.1). And once again, there is an occurrence in the *Criterion* (3.3):

ἐκ πόσων μὲν οὖν καὶ οἷων καὶ τίνα τρόπον συνέστηκεν τὸ κριτήριον ὑποτετυπώσθω διὰ τῶν ἐφωδευμένων. ἐπεὶ δὲ...

Let [the questions] out of how many and what sort of things and in what manner the criterion is composed *have been sketched* by means of the things that have been treated methodically. But since...

The only other occurrence in a text from antiquity in the *TLG* corpus is in Hephaestion’s paraphrase (1.20) of *Tetrabiblos* 2.4.¹⁵

These are just two of many words and phrases that turn up in more than one work attributed to Ptolemy but hardly anywhere else — in some cases

¹⁴ Although the phrase κατὰ τὸ κεφαλαϊῶδες does not occur in the *Geography*, Ptolemy’s prose description of the known world and its principal features in *Geography* 7.4 is characterized in the chapter title as well as at the end of the preceding chapter as a ὑπογραφὴ κεφαλαϊῶδης, ‘summary caption’; this might have triggered a memory of an expression encountered in other works of Ptolemy’s.

¹⁵ There is an instance in the astrological dialogue *Hermippus* (ed. Kroll and Viereck, p. 57 line 23), a work of disputed authorship but definitely of Byzantine date.

nowhere — in texts written up to the end of the fourth century of our era. Table 2 summarizes the patterns of occurrence of fourteen such verbal fingerprints (see the detailed discussion in the appendix to this paper). Every work of continuous prose surviving even partially in Greek in the accepted Ptolemaic corpus (i.e. excluding the *Handy Tables* and the *Canobic Inscription*) is linked by at least one shared expression to at least two other works. As one might expect, the *Almagest* has the largest number of shared expressions — eight of the fourteen — while the *Tetrabiblos* has seven; but the *Criterion* also has seven, making it in this peculiar sense one of the most characteristic works in the Ptolemaic corpus! This is the more remarkable, because the *Almagest* runs to more than 1150 Teubner pages, and the *Criterion* to just 23.

Either the *Criterion* is indeed by Ptolemy, then, or it was composed by someone after Ptolemy using a vocabulary that was strongly influenced, consciously or unconsciously, by Ptolemy's. It is not a work to which Ptolemy's name was accidentally attached, say, merely because it came after genuine works of Ptolemy in a manuscript or because it was written by a different Ptolemy. But the same apparent remoteness of its subject matter from that of Ptolemy's 'scientific' treatises that has led many to doubt its authenticity argues against its being a deliberate forgery or a mistaken ascription of an imitator's composition to the master. The *Criterion* is thus validated as an authentic work of Ptolemy's, and the features of it — such as its very subject matter — that have given rise to doubts about its authorship actually broaden our understanding of Ptolemy's system of thought and perhaps also its development.

The verbal fingerprint test is obviously inapplicable to works that come down to us only in languages other than Greek. In the case of two of the astronomical texts ascribed to Ptolemy, the *Planetary Hypotheses* and the *Analemma*, Greek text whose authenticity is confirmed by verbal fingerprints survives for less than half of each work as represented respectively in Arabic and in Latin. The *Analemma*'s Greek remnants reach us through palimpsest leaves (sixth century?) in the manuscript *Ambrosianus* L99sup that correspond to roughly the middle third of the ostensibly complete text in William of Moerbeke's translation; the parts not covered by the palimpsest were obviously present in the lost Greek manuscript used by William, and there is no reason to suspect that they are inauthentic.¹⁶ The Greek *Planetary Hypotheses*, on the other hand, is roughly the first half of Book 1 as we know it from the Arabic, breaking off in mid-sentence, which suggests descent from a mutilated exem-

¹⁶ William's autograph translation of the *Analemma* in *Ottob. lat.* 1850 cuts off abruptly at the bottom of the last page of a quire, with the first of what the text leads the reader to expect will be a set of tables, and, unlike the other translations in the manuscript, this one lacks a subscription giving the work's title and the date of the translation's completion. There may thus have been a continuation for which we have neither Greek nor Latin.

	Alm	Phas	PH	ACHT	Ana	Tetra	Cirit	Harm	Geog	other authors (up to c. AD 400)
ἀμετάπιστος	1						2			
ἐπιπολυπραγμονέω						1	1			
ἐγκατανόητος	28					1		2		Polybius (1) Hipparchus (2) Pappus*† (1) Theon Alex.*† (3) Porphyry*† (2) Serenus (1)
ἐμβλεθδευτον	2		1							Theon Alex.*† (3)
ἐφωδευμένος (cf. προσφωδευμένος)	7				1	4	2		1	
ἴδιο τροπία	3					35	1	1	1	Aristides Quintilianus (1) Cleomedes (1) Hephaestion*† (18) ps-Galen <i>De Decubitu</i> (1)
κατὰ συνεργισμὸν			1						2	Hipparchus (2)
κατὰ τὸ κεφαλαϊώδες	1							5	1	Hephaestion*† (2)
κατὰ τὸ ὀλοσ/ερέες / ὀλοσ/ερέστερον	5			1		2				Geminus (2) Hephaestion*† (2)
κατὰ τὸν ἀρμόζοντα... λόγον / τρόπον προεντάσσω	4	1				3		1		
προσφωδευμένος	9									Heron <i>Metrica</i> (1) Asclepiodotus (1) Philo Judaeus (1)
προσπαραμυθῶμαι		1						2	1	Strabo (1)
προυποτετυπώσθω / προυποτετυπώσθωσαν						2				Hephaestion*† (1)
συνεχέστερα παρατήρησις	1		1			2	1	4	3	Theon Alex.*† (2) Hephaestion* (1)
ὑποτετυπώσθω / ὑποτετυπώσθωσαν (cf. προυποτετυπώσθω)						2	1	4	3	

* Text reflecting influence of Ptolemy's works. † At least one instance is a paraphrase or quotation from Ptolemy.

Table 2. Some of Ptolemy's verbal fingerprints

plar; and there are changes of subject matter soon after this point as well as between Books 1 and 2 such that no one having just the part existing in Greek would have been able to predict how Ptolemy was going to continue through the rest of the work. But testimonia in Proclus and Simplicius correspond to passages in both Books 1 and 2 that survive only in Arabic, confirming their authenticity (or at a minimum, that these passages existed in Greek in late antiquity).¹⁷ The *Planispherium* seems to be adequately accredited by its references to the *Almagest* and dedication to Syros and by the consistency of its subject matter and mathematical methods with the authenticated astronomical writings, notwithstanding that the only testimonium for it in Greek is its apparent listing in the *Suda* (s.v. Πτολεμαῖος ὁ Κλαύδιος χρηματίσας) by the title ἄπλωσις ἐπιφανείας σφαιράς, ‘flattening of a surface of a sphere’.

The *Optics* confronts us with the least satisfactory evidence for its authorship among all the texts whose ascriptions to Ptolemy are not patently spurious. We have testimonia from Simplicius and Damianus in late antiquity and from Symeon Seth in the eleventh century to the existence in Greek of an *Optics* ascribed to Ptolemy, but they do not correspond to passages in the extant, mutilated Latin *Optics*. The Simplicius passage (*In Arist. de Caelo*, ed. Heiberg, *Simplicius*, p. 20) cites both Ptolemy’s *Optics* and another work of Ptolemy’s ‘on the elements’ (ἐν τῷ περὶ τῶν στοιχείων βιβλίῳ) for a non-Aristotelian principle that the elements — apparently including both the four ‘mundane’ elements and the fifth ethereal one — have a natural rectilinear motion *only* when they are outside their natural places; the fact that this principle is also found in *Planetary Hypotheses* Book 2 strengthens the case that the *Optics* that Simplicius knew was indeed by Ptolemy.¹⁸ Arguments for the authenticity of the extant *Optics*, however, rest largely on a general sense that it exhibits an intellectual level, engagement with contemporary philosophical concerns, and empirical approach worthy of Ptolemy. Moreover, the extended mathematical discussion of the effect of refraction on observed positions of heavenly bodies in *Optics* 5.23–30 ties one aspect of the treatise’s subject to Ptolemy’s astronomical interests. A still stronger indication that the author was an astrono-

¹⁷ The end of the authentic Greek text as given, e.g., in *Vat. gr.* 1594 is at Heiberg, *Opera astronomica minora*, p. 104, line 23 after ἴσοπαχῶς in the middle of the description of the model for Saturn; the continuation in some manuscripts, which Heiberg retains in his edition, is a mechanical duplication of the preceding description of Jupiter’s model with the numerical parameters replaced by blank spaces. Proclus, *In Timaeum* 258a summarizes material from the later part of *Planetary Hypotheses* Book 1, whereas Simplicius, *In Arist. de Caelo* (ed. Heiberg, p. 456) paraphrases a passage in Book 2.

¹⁸ cf. Nix’s translation in Heiberg, *Opera astronomica minora*, pp. 112–13. However, since Simplicius also cites the peripatetic Xenarchus and Plotinus in the same context, one cannot maintain that this principle of the rectilinear motion of displaced elements was exclusive to Ptolemy.

mer is that the circular bronze plaque used for the measurements of angles of reflection and refraction in 3.8 and 5.8 is to be inscribed with a division of the circle into degrees, since this appears to be one of only two known ancient instances of use of degrees as a measure of arcs or angles outside of astronomy, astrology, and geography.¹⁹ Though one might wish for something in the *Optics* that marks it specifically as Ptolemy's work, this is barely enough, I believe, to make the transmitted attribution to him convincing.

3. Lost works

It is impossible to be certain how much of Ptolemy's literary production is lost, but from the indications that we have, it is likely to have been significantly less than what survives. Leaving aside the portions known to be missing from extant works — the first book and the conclusion of the fifth of the *Optics*, the last three chapters of *Harmonics* Book 3, and the promised tables at the ends of the *Analemma* and *Planetary Hypotheses* — the only non-extant text explicitly mentioned in any of the surviving ones is the 'dedicated treatise on this subject' (ἡ κατ' ἴδια σύνταξις τῆσδε τῆς πραγματείας) cited at the opening of the *Phaseis*, in which Ptolemy states that he provided a full mathematical treatment of the conditions determining the dates of first and last morning and evening risings of the fixed stars.²⁰ Since the *Suda* lists among Ptolemy's works 'two books on phases and weather-signs of fixed stars' (περὶ φάσεων καὶ ἐπισημασιῶν ἀστέρων ἀπλανῶν βιβλία β), whereas the extant *Phaseis* (transmitted under a slightly different title, φάσεις ἀπλανῶν ἀστέρων καὶ συναγωγὴ ἐπισημασιῶν) is in just one book, it is generally assumed that what we have is Book 2 of a work, the lost Book 1 of which is summarized in its opening sentence, but Ptolemy's wording does not seem to fit a back-reference to a previous part of the same treatise.

A scholion in some manuscripts of the *Almagest* cites a work by Ptolemy 'on paradoxical phases of Venus'.²¹ The 'paradoxical' phenomena in question clearly consist of Venus's highly variable intervals of invisibility, in particular around inferior conjunction, which are a topic dealt with in *Almagest* 13.8.²² The scho-

¹⁹ The other instance is a circular plate graduated in degrees, which forms part of a set of surveyor's instruments of unknown provenance and dating from late antiquity; see Turner, *Mathematical Instruments*, pp. 10–11 and fig. 12d.

²⁰ Occasionally Ptolemy employs *πραγματεία* in the sense of 'treatise' (e.g. *Almagest* 13.11), but it can hardly have this meaning here since *σύνταξις* already designates a composition in its own right.

²¹ Jones, 'A Posy', esp. pp. 75–77.

²² The qualification 'paradoxical' does not appear in the *Almagest*, but is applied by Proclus, *Hypotyposis* 1.17–22 and 7.9–18 to these phenomena and certain visibility phenomena of Mercury also treated in *Almagest* 13.8. Proclus may be making reference to the separate work cited in the scholion as well as to the *Almagest*.

lion is not referring to *Almagest* 13.8, however, since it states that the work in question contained an explanation of positional terminology in Babylonian planetary observation reports, which is in fact not to be found anywhere in the *Almagest*. Like the lost work on stellar visibility, this seems to have been Ptolemy's in-depth handling of a subject that he treated more cursorily in the *Almagest*.

In his commentary on the *Almagest*, Pappus supplements his discussion of the armillary astrolabe whose construction Ptolemy sets out in *Almagest* 5.1 with information about a more complex version of the instrument, with nine rings instead of seven, derived from another work of Ptolemy's that Pappus designates as 'the constructed instrument that is called *meteoroskopeion*' (ἐν δὲ τῷ διακατασκευασμένῳ ὀργάνῳ ὃ καλεῖται μετεωροσκοπεῖον).²³ References to the *meteoroskopeion* also appear in Ptolemy's *Geography* 1.3 and Proclus, *Hypotyposis* 6, though without citation of a specific lost writing.²⁴

If the foregoing trio of lost astronomical writings could be classified under the heading, 'more of the same,' others that receive mostly glancing references in later authors hint at facets of Ptolemy's intellectual activity that the extant works represent poorly if at all, especially concerning physics (in the ancient sense). The very first work of Ptolemy's listed in his *Suda* article is *Mechanics* (Μηχανικά) in three books. We know nothing about its contents beyond the implication of its title that it concerned manmade devices and machines, but, presuming it was authentic, it would have counted among Ptolemy's major compositions, and one would imagine that it took at least as theoretical an approach as Heron's *Mechanics* (which interestingly was also in three books). Works *On the Elements* (περὶ τῶν στοιχείων) and *On Weights* (περὶ ῥοπῶν) — or could they be a single work designated by two different descriptive quasi-titles? — are cited by Simplicius, *In Arist. De Caelo* (ed. Heiberg, pp. 20 and 710 for discussions of the behavior of mundane material bodies in and out of their natural places, while Eutocius, *In Archim. De Planorum Equil.* (ed. Heiberg, p. 306) attributes to Ptolemy's *On Weights* a definition of weight.

Simplicius, *In Arist. De Caelo* (ed. Heiberg, p. 9) also refers to a work in a single book (μονόβιβλος) called *On Dimension* (περὶ διαστάσεως), in which Ptolemy presented the same argument as appears in the *Analemma* that there can be only three orthogonal dimensions. Lastly, we have no title for the text ('in some book', ἐν τινι βιβλίῳ) in which, according to Proclus, *In Eucl. Elementa* (ed. Friedlein, pp. 191 and 362–67) and al-Nayrīzi's commentary on the *Elements* (ed. Besthorn & Heiberg, p. 118; ed. Curtze, pp. 65–66), Ptolemy

²³ The verb διακατασκευάω is a hapax legomenon, and perhaps the passage is corrupt, but Pappus clearly has a text attributed to Ptolemy since he follows the phrase quoted above with 'he says' (λέγει).

²⁴ Rome, 'L'Astrolabe'.

attempted a proof of Euclid's fifth postulate and applied this result to variant proofs of several propositions in *Elements* Book 1.

4. Chronology of the works

Knowing the order in which Ptolemy wrote his works might cast some light on the development of his thought. The cross references to the *Almagest* in the majority of his surviving astronomical writings as well as in the *Tetrabiblos* and *Geography* suffice to show that all these works were completed, if not entirely written, after the *Almagest*. This must also be true of the *Phaseis* and the lost book on the mathematical theory of stellar visibility phenomena summarized in the *Phaseis*'s introduction, since in *Almagest* 8.6 Ptolemy writes of stellar visibility theory as a complex and uncertain undertaking that he has chosen to dispense with 'for the time being' (ἐπὶ τοῦ παρόντος). The *Almagest* in turn cites astronomical observations that Ptolemy asserts that he made over a span of years from 127 through 141, and even if some of these are not genuine and untampered observations, one can safely presume that he would not have claimed to make an observation at a date manifestly before he was capable of doing so. Moreover, the allusion in *Almagest* 4.9 to repudiated earlier astronomical parameters that can be identified in the *Canobic Inscription* establishes that the treatise was not completed in the form we have it before the explicit date of the inscription's erection, the tenth regnal year (according to the Egyptian calendar) of Antoninus Pius, or AD 146–147. Hence almost all Ptolemy's other works on astronomical, astrological, and cartographical subjects are known to have been finished in the period after the *Almagest*, whereas only the *Canobic Inscription*, which is not a writing in the normal sense, can be dated with certainty to the twenty-year interval of Ptolemy's career preceding the *Almagest*'s completion.

Certain developments in Ptolemy's geographical knowledge and astronomical theories make it possible to obtain a plausible sequence for some of the post-*Almagest* works. In *Almagest* 2.6, Ptolemy asserts that the regions around the Earth's equator are 'untrodden' (ἄτριπτοι) by people from his part of the world (ἢ καθ' ἡμᾶς οἰκουμένη) so that one can only guess what the climate there is like. The astrological geography and ethnography of *Tetrabiblos* 2.2 likewise extends southward only as far as the equator. In the *Geography*, however, Ptolemy has learned (from the writings of Marinus of Tyre) of peoples and places located, so he believes, as far south as $16\frac{5}{12}^{\circ}$ south of the equator. Now the core of the *Geography* is a list of several thousand localities with their coordinates in longitude and latitude, grouped by 'provinces and satrapies' and ordered appropriately to provide the basis for systematically drawing a map of the known part of the world; a few hundred of these are singled out as 'noteworthy cities' (πόλεις ἐπίσημοι). The table of Noteworthy Cities in

the *Handy Tables* turns out to comprise this same subset from the *Geography*, listed in the same order which had been determined by practical convenience for drawing the map. Turning now to astronomical considerations, the models and parameters built into the *Handy Tables* and presented in the *Planetary Hypotheses* occasionally differ from those of the *Almagest* and each other. In particular, the distinct models for the planets' motions in latitude in the three works make best sense as resulting from a process of simplification in which the *Planetary Hypotheses* represents the final stage.²⁵

The concluding section of the *Canobic Inscription* associates the heavenly bodies and the mundane elements one-to-one (or in a few cases two-to-one) with a scale of musical pitches, such that the pitches ascend with increasing distance from the center of the cosmos. This same correlation, which so far as we can tell was devised by Ptolemy himself, was discussed as a harmonic foundation of astrological affinities between the heavenly bodies in *Harmonics* 3.16, one of the lost three closing chapters of the *Harmonics*; the evidence, which is compelling, is a surviving fragment either from the chapter itself or from a scholion or commentary.²⁶ No trace of the scheme can be found in the *Tetrabiblos*, though a different application of harmonics to astrological relations is introduced in *Tetrabiblos* 1.14. The *Harmonics* thus seems likely to have been a comparatively early work of Ptolemy's, perhaps completed before the *Almagest*. More subjectively, the epistemological discussions of the *Criterion* impress one as both simpler and cruder than those of the *Harmonics*, suggesting that the *Criterion* could belong to the very beginning of Ptolemy's career.²⁷

For the remaining major treatise, the *Optics*, three considerations have been adduced as favoring a comparatively late date. First, there is the contrast between the extended discussion of refraction as affecting observed positions of heavenly bodies in *Optics* 5.23–30, which we have already mentioned, and the absence of anything comparable in the *Almagest*.²⁸ Second, in *Almagest* 1.3 and 9.2 Ptolemy refers to the phenomena that apparent sizes of heavenly bodies, and apparent angular distances separating heavenly bodies, appear larger when they are near the horizon, but in one passage he mistakenly attributes the effect to refraction in the atmosphere while in the other he provides no cause; by way of contrast, in *Planetary Hypotheses* 1B.7 and in *Optics* 3.59 he explains the phenomena psychologically, which is essentially correct.²⁹ Third, in *Geography* 1.1 Ptolemy seems to invoke the theory (familiar, e.g., from Euclid's

²⁵ Swerdlow, 'Ptolemy's Theories', pp. 41–71.

²⁶ Swerdlow, 'Ptolemy's Harmonics'.

²⁷ Feke, 'Mathematizing the Soul', offers further more or less subjective arguments that the *Criterion* antedated the *Harmonics*.

²⁸ Smith, *Ptolemy's Theory of Visual Perception*, p. 2.

²⁹ Smith, *Ptolemy's Theory of Visual Perception*, p. 2.

Optics) that visual perception occurs through rectilinear visual rays fanning out from the eyes with gaps between the rays that enlarge with greater distance, whereas in *Optics* 2.50–51 he rejects the concept of discrete rays.³⁰ However, none of these considerations constitutes a truly compelling argument for the sequence of the works in question.

Table 3 summarizes what we know or can plausibly guess about the sequence of Ptolemy's writings, where the *Canobic Inscription* and *Almagest* serve as the chronological anchor.

<i>Firmly dated</i>	<i>Subjectively dated</i>
<i>Canobic Inscription</i> (AD 147/147)	<i>On the Criterion</i>
<i>Almagest</i>	<i>Harmonics</i>
<i>Tetrabiblos</i>	Treatise on theory of stellar visibility (possibly Book 1 of <i>Phaseis</i>)
<i>Handy Tables</i>	<i>Phaseis</i> (possibly Book 2)
<i>Arr. and Comp. Handy Tables</i>	
<i>Geography</i>	
<i>Planetary Hypotheses</i>	<i>Optics</i>

Table 3. A plausible chronological sequence for some of Ptolemy's works. The *Planisphaerium* is also firmly dated to after the *Almagest*, and the work describing the *meteoroskopeion* to between the *Almagest* and the *Geography*, but their places in the sequence cannot be further narrowed.

5. Range and connectedness of Ptolemy's interests

Table 4 groups Ptolemy's works, both extant and lost, according to the disciplines by which one would most likely classify them on the basis of their overall subject matter. The primacy of astronomy — defined as the science concerning the nature, movements, and phenomena of the heavenly bodies in their own right — in this list is obvious, both by the number of the works and by their including the *Almagest*, the largest (by a considerable margin) and most highly structured treatise among them.³¹ Moreover, significant references to astronomy occur in the *Harmonics*, *Tetrabiblos*, *Geography*, and *Optics*. At the same time, taking the lost works into consideration reinforces the realiza-

³⁰ Berggren and Jones, *Ptolemy's Geography*, p. 57, n. 2.

³¹ The *Geography* comes next in bulk, but approximately five of its eight books consist simply of the cartographical data for constructing maps, and most of the eighth book is devoted to captions for the regional maps.

tion that Ptolemy was also deeply interested in phenomena of the sublunary world, whether these phenomena were such as he believed to be amenable to mathematical modelling or not. Conspicuously absent from the list is any work on a strictly biological topic.

<i>Discipline</i>	<i>Work</i>	<i>Preservation</i>
Astronomy	<i>Canobic Inscription</i>	Greek
	<i>Almagest</i> (13 books)	Greek
	<i>Arr. and Comp. Handy Tables</i>	Greek
	<i>Handy Tables</i>	Greek
	<i>Planetary Hypotheses</i> (2 books)	Greek (parts Arabic)
	<i>Phaseis</i> (possibly Book 2)	Greek
	Treatise on theory of stellar visibility (possibly Book 1 of <i>Phaseis</i>)	Lost
	<i>On Paradoxical Phases of Venus</i>	Lost
	Description of the <i>meteoroskopeion</i>	Lost
	<i>Analemma</i>	Latin (parts Greek)
	<i>Planisphaerium</i>	Arabic/Latin
Astrology	<i>Tetrabiblos</i> (4 books)	Greek
Cartography	<i>Geography</i> (8 books)	Greek
Epistemology	<i>On the Criterion</i>	Greek
Music theory	<i>Harmonics</i> (3 books)	Greek
Optics	<i>Optics</i> (5 books)	Latin
Physics and Mechanics	<i>Mechanics</i> (3 books)	Lost
	<i>On the Elements</i>	Lost
	<i>On Weights</i>	Lost
Mathematics	<i>On Dimension</i>	Lost
	Work related to Euclid's <i>Elements</i>	Lost

Table 4. Ptolemy's known works arranged by primary discipline

Cutting across classification by discipline are certain prevailing themes. One that is especially prominent in several of the more ambitious treatises is epistemology. Thus the *Harmonics* and the *Almagest* are both deeply concerned with appropriate strategies for applying sense perception (i.e. empirical observations and measurements with or without specially constructed apparatus) and reason (in particular mathematical analysis) to deduce knowledge of the 'hypotheses' or models underlying the phenomena respectively of musical pitch relations and

the apparent behavior of the heavenly bodies; the explicit discussions in the *Harmonics* of the complementary roles of sense perception and reason as criteria (in the Greek philosophical sense) turn out to be highly relevant for grasping the more complex though largely unarticulated deductive structures of the *Almagest*. Book 1 of the *Geography* has an extended discussion of the relative value of different kinds of empirical data for determining absolute and relative locations of terrestrial places, and of methods for evaluating and correcting distorted data. The *Optics*, as a systematic study applying empirical observation, experiment, and deductive analysis to the nature visual perception and the relations (which are often subject to error) between perceived bodies and our perceptions of them, could be described as a study in the scientific epistemology of epistemology itself. In the light of these sophisticated treatments of the processes of acquiring knowledge about the external world, we might be less surprised that Ptolemy wrote a monograph largely devoted to the general topic of criteria than that this part of *On the Criterion* appears comparatively banal and disconnected from scientific applications.

The two central principles of Ptolemy's cosmology are the (originally Aristotelian) four-plus-one elements theory and the division of the cosmos into an inner 'sublunary' sphere in which the four elements earth, water, air, and fire predominate and an outer celestial spherical shell composed of bodies of ether. In the *Almagest* these principles are mostly kept in the background, though Ptolemy does ground his assumption that the heavenly bodies move with eternally uniform circular revolutions in a characterization of etherial bodies as eternal, unchanging, and divine (see for example 13.2). The three-dimensional geometry of these celestial bodies of ether, both visible and invisible, is the chief subject of *Planetary Hypotheses* Book 2, while the *Tetrabiblos* invokes the physical relationship between the celestial outer part of the cosmos and the enclosed sublunary sphere, such that the heavenly bodies are agents of generation and change in the complex, irregularly evolving sublunary world, as the rationale for the viability but inherent inexactness of astrological prediction. Among the non-astral-sciences works, the *Criterion* is particularly interesting for offering a materialistic theory of the composition of human souls, according to which ether is present in the soul and responsible for its intellectual capacity. This would provide a bridge between Ptolemy's notions of the human soul as having mathematical structures (*Harmonics* Book 3) and as having the power to introduce mathematically structured features into the external environment — by making music (*Harmonics* Book 1) and even simply by seeing through the rectilinear emission of a visual ray (*Optics*) — and his belief that the coordinated motions of the celestial etherial bodies are generated by celestial souls (*Planetary Hypotheses* Book 2).

Lastly, didactically appropriate, mathematically defined modes of representation of aspects of the cosmos are a broad concern of Ptolemy's. The *Plani-*

spherium, for example, is about representing celestial circles and revolutions in a single plane through stereographic projection, while in the *Almagest* and *Planetary Hypotheses* Ptolemy writes respectively about the formats of numerical tables and mechanical constructions as means of displaying underlying realities behind astronomical phenomena. Ptolemy's most extensive contribution to this theme, however, is the *Geography*, since this work is more or less entirely concerned with the best ways of displaying geographical information on planar surfaces and globes, in the latter case providing a terrestrial counterpart to the construction of a star globe in *Almagest* Book 8.

Appendix: Words and phrases characteristic of Ptolemy

The fourteen expressions discussed in this appendix are almost certainly not an exhaustive list of those that occur in more than one of Ptolemy's works but rarely or never in other authors; they were found by reading the texts with an eye for candidate expressions, followed by a TLG search. Unless otherwise noted, occurrences of the expressions are according to the editions used in the TLG. Occurrences in authors later than Hephæstion are excluded.

ἀμετάπιστος, 'not subject to change of belief'. While ἀμετάπειστος, thus spelled, is a frequent term in Aristotle and hence also in the Aristotelian commentators (as well as Plutarch and, with one instance, Diodorus), ἀμετάπιστος appears to be distinctive to Ptolemy: *Almagest* 1.1, *Criterion* 2.6 and 12.5. The two words are not identical in meaning, since ἀμετάπειστος is applicable to a belief or a believer that is not subject to alteration, whereas ἀμετάπιστος characterizes an object of thought *about* which belief cannot be altered.

ἐπιπολυπραγμονέω, 'to busy oneself additionally'. Unique to Ptolemy: *Tetrabiblos* 3.6.4, *Criterion* 8.3.

εὐκατανόητος, 'easily comprehended'. Very frequent in the *Almagest* (28 instances); also *Tetrabiblos* 1.11.5, *Harmonics* 1.1 and 1.11. Instances in texts not obviously influenced by Ptolemy: Polybius 18.30.11, Hipparchus *In Arati et Eudoxi phaenomena* 1.1.11 and 2.4.6, Serenus, *De sectione conii* ed. Heiberg p. 250 line 25. In texts influenced by Ptolemy: Porphyry, *Commentary on Harmonics* ed. Düring p. 20 line 9 (quoting *Harmonics*) and p. 133 line 13 (paraphrasing *Harmonics*), Pappus, *Commentary on Almagest* ed. Rome p. 98 line 27 (quoting Ptolemy), Theon of Alexandria, *Commentary on Almagest* ed. Rome p. 502 line 17 (quoting Ptolemy), p. 564 line 7, and p. 569 line 7. Ptolemy may have picked up the word from familiarity with Hipparchus.

εὐμεθέδευτον, 'easily carried out'. *Almagest* 1.10 and 13.4, *Planetary Hypotheses* 1.2. Theon of Alexandria, *Commentary on Almagest* ed. Rome

p. 451 line 2 (quoting Ptolemy), p. 602 line 8, *Great Commentary on Handy Tables* ed. Mogenet and Tihon v. 1 p. 102 line 20.

ἐφωδευμένος, ‘worked out’ or ‘carried out’. Unique to Ptolemy: *Almagest* 2.13, 3.1, 3.4, 6.5, 12.9, 13.8, 13.11, *Analemma* ed. Heiberg p. 195 line 8, *Tetrabiblos* 3.1.1, 3.12.1, 4.9.1, 4.10.1, *Geography* 8.1.2, *Criterion* 3.3, 15.1. The compound προεφωδευμένος, ‘previously worked out’, occurs in *Almagest* 3.4, 9.9, 12.2, 12.7, 12.9 (3 instances), 13.4 (2 instances), and otherwise only in Strabo 12.8.8.

ἰδιοτροπία, ‘characteristic tendency’. Very frequent in the *Tetrabiblos* (35 instances); also *Almagest* 1.1, 8.4, 9.2, *Harmonics* 3.7, *Geography* 2.1.8, *Criterion* 4.3. In texts not obviously influenced by Ptolemy: Aristides Quintilianus 3.26, Cleomedes 2.4, pseudo-Galen, *Prognostica de decubitu*, ed. Kühn (v. 19) p. 538 line 5. Influenced by Ptolemy: Hephaestion (18 instances). In the *Tetrabiblos* (and hence also Hephaestion) the term takes on a quasi-technical status.

κατὰ συνεγγισμὸν + genitive, ‘by adjustment to fit’. In this usage, unique to Ptolemy: *Planetary Hypotheses* 1.5, *Geography* 1.13.1, 2.1.2. The only other occurrences of κατὰ συνεγγισμὸν, without genitive object and with the meaning ‘by way of approximation’, are in Hipparchus, *In Arati et Eudoxi phaenomena* 1.11.7 and 2.4.6.

κατὰ τὸ κεφαλαιῶδες, ‘in summary manner’. *Almagest* 2.1, *Tetrabiblos* 1.3.20, 2.4.1, 2.14.12, 3.14.9, 3.4.4, *Criterion* 15.1. Influenced by Ptolemy: Hephaestion 1.20.1 (paraphrasing Ptolemy), 1.25.25.

κατὰ τὸ ὀλοσχερές, ‘in a rough manner’. *Almagest* 9.5, *Tetrabiblos* 3.3.5. In texts not obviously influenced by Ptolemy: Geminus 2.20, 18.14. Influenced by Ptolemy: Hephaestion 1.1.13, 2.2.6 (paraphrasing Ptolemy). κατὰ τὸ ὀλοσχερέστερον, ‘in a rougher manner’. *Almagest* 6.11, 8.6, 10.6, 11.5, *Arrangement and Computation of the Handy Tables* 1 (ed. Heiberg p. 161 line 1), *Tetrabiblos* 3.2.6.

κατὰ τὸν ἀρμόζοντα... λόγον/τρόπον, ‘in the rationale/manner fitting for...’ Unique to Ptolemy: *Tetrabiblos* 1.1.2, 3.7.1, 4.10.27^{alt},³² *Harmonics* 2.9.

προσεντάσσω, ‘to insert additionally’. *Almagest* 6.11, 8.3 (2 instances), 8.6, *Phaseis* 9 (ed. Heiberg p. 12 line 14). In texts not obviously influenced by Ptolemy: Heron, *Metrica* 2.15, Asclepiodotus 6.1, Philo Judaeus, *In Flaccum* 131.

³² This refers to the ‘alternate’ conclusion of the *Tetrabiblos*’s final chapter, which Boll and Hübner did not adopt but is now widely regarded as the authentic version.

προσπαραμυθέομαι, ‘to remark additionally’. Unique to Ptolemy: *Phaseis*, ed. Heiberg p. 13 line 21, *Arrangement and Computation of the Handy Tables*, ed. Heiberg p. 185 line 6, *Harmonics* 3.4, *Criterion* 4.2, 6.1.

συνεχέστερα παρατήρησις, ‘more sustained observation’. *Almagest* 1.8, *Planetary Hypotheses* 1.2. Influenced by Ptolemy: Theon, *Commentary on Almagest*, ed. Rome p. 338 line 15, p. 437 line 14 (quoting Ptolemy).

ὑποτετυπώσθω/ὑποτετυπώσθωσαν, ‘let there have been sketched’. *Tetrabiblos* 2.4.1 (Boll adopts the variant reading ὑποτυπούσθω), 4.8.6, *Harmonics* 1.4, 2.3, 2.11, 3.4, *Geography* 1.2.1, 1.18.1, 2.1.1, *Criterion* 3.3. Influenced by Ptolemy: Hephaestion 1.25.25. προυποτετυπώσθω/προυποτετυπώσθωσαν, ‘let there have been sketched beforehand’. *Tetrabiblos* 1.3.20 (variant reading not adopted by Boll or Hübner), 4.10.13. Influenced by Ptolemy: Hephaestion 2.26.12 (quoting Ptolemy).

Bibliography

- Berggren, J. Lennart, and Alexander Jones, *Ptolemy's Geography. An Annotated Translation of the Theoretical Chapters*, Princeton: Princeton University Press, 2000.
- Boll, Franz, ‘Studien über Claudius Ptolemäus. Ein Beitrag zur Geschichte der griechischen Philosophie und Astrologie’, *Jahrbücher für classische Philologie*, suppl. 21 (1894), pp. 49–224.
- Bowersock, Glen Warren, *Greek Sophists in the Roman Empire*, Oxford: Oxford University Press, 1969.
- Brunt, Peter A., ‘The Bubble of the Second Sophistic’, *Bulletin of the Institute of Classical Studies* 39 (1994), pp. 25–52.
- Caussin de Perceval, Jean Jacques Antoine, ‘Mémoire sur l’Optique de Ptolémée, et sur le projet de faire imprimer cet ouvrage d’après les deux manuscrits qui existent à la Bibliothèque du Roi’, *Histoire et mémoires de l’Institut royal de France* 6 (1922), pp. 1–43.
- Feke, Jacqueline, ‘Mathematizing the Soul. The Development of Ptolemy’s Psychological Theory from *On the Kritêrion and Hêgemonikon* to the *Harmonics*’, *Studies in History and Philosophy of Science* 43 (2012), pp. 585–94.
- Hamilton, Norman T., Noel M. Swerdlow, and Gerald J. Toomer, ‘The Canobic Inscription. Ptolemy’s Earliest Work’, in J. Lennart Berggren and Bernard R. Goldstein (eds), *From Ancient Omens to Statistical Mechanics. Essays on the Exact Sciences Presented to Asger Aaboe*, Copenhagen: Munksgaard, 1987, pp. 55–73.
- Heiberg, Johan L., *Opera astronomica minora*, Leipzig: Teubner, 1907 [*Claudii Ptolemaei opera quae exstant omnia*, vol. II].
- Jan, Karl von, *Musici Scriptores Graeci*, Leipzig: Teubner, 1895.
- Jones, Alexander, ‘William of Moerbeke, the Papal Greek Manuscripts, and the Collection of Pappus of Alexandria in Vat. gr. 218’, *Scriptorium* 40 (1986), pp. 16–31.

- Jones, Alexander, 'Pseudo-Ptolemy *De Speculis*', *SCIAMVS* 2 (2001), pp. 145–86.
- Jones, Alexander, 'A Posy of *Almagest* Scholia', *Centaurus* 45 (2003), pp. 69–78.
- Juste, David, 'Pseudo-Ptolemy, *Centiloquium*', *Ptolemaeus Arabus et Latinus. Works*, URL = <http://ptolemaeus.badw.de/work/24> (update: 03.10.2017).
- Knorr, Wilbur R., 'Archimedes and the Pseudo-Euclidean *Catoptrics*. Early Stages in the Ancient Geometric Theory of Mirrors', *Archives Internationales d'Histoire des Sciences* 35 (1985), pp. 28–105.
- Moraux, Paul, *Galien de Pergame. Souvenirs d'un médecin*, Paris: Les Belles Lettres, 1985.
- Nutton, Vivian, 'Galen in the Eyes of his Contemporaries', *Bulletin of the History of Medicine* 58 (1984), pp. 315–24.
- Rome, Adolphe, 'L'Astrolabe et le Météoroscope d'après le commentaire de Pappus sur le 5^e livre de l'Almageste', *Annales de la Société Scientifique de Bruxelles* 47, 2 (1927), pp. 77–102.
- Rome, Adolphe, 'Notes sur les passages des Catoptriques d'Archimède conservés par Théon d'Alexandrie', *Annales de la Société Scientifique de Bruxelles* 52, 1 (1932), pp. 30–41.
- Rose, Valentin, *De Aristotelis librorum ordine et auctoritate commentatio*, Berlin: Reimer, 1854.
- Sezgin, Fuat, *Geschichte des arabischen Schrifttums*, vol. VII: *Astrologie – Meteorologie und Verwandtes bis ca. 430 H*, Leiden: Brill, 1979.
- Siebert, Harald, *Die ptolemäische Optik in Spätantike und byzantinischer Zeit: Historiographische Dekonstruktion, textliche Neuerschließung, Rekontextualisierung*, Stuttgart: Steiner, 2014.
- Smith, A. Mark, *Ptolemy's Theory of Visual Perception. An English Translation of the Optics with Introduction and Commentary*, Philadelphia: American Philosophical Society, 1996.
- Staden, Heinrich von, 'Galen and the "Second Sophistic"', *Bulletin of the Institute of Classical Studies* 41 (1997), pp. 33–54.
- Strohmaier, Gotthard, 'Galen's Not Uncritical Commentary on Hippocrates' *Airs, Waters, Places*', *Bulletin of the Institute of Classical Studies* suppl. 83, 2 (2004), pp. 1–9.
- Swerdlow, Noel M., 'Ptolemy's *Harmonics* and the "Tones of the Universe" in the Canobic Inscription', in Charles Burnett, Jan P. Hogendijk, Kim Plofker and Michio Yano (eds), *Studies in the History of the Exact Sciences in Honour of David Pingree*, Leiden: Brill, 2004, pp. 137–80.
- Swerdlow, Noel M., 'Ptolemy's Theories of the Latitude of the Planets in the *Almagest*, *Handy Tables*, and *Planetary Hypotheses*', in Jed Z. Buchwald and Allan Franklin (eds), *Wrong for the Right Reasons*, New York: Springer, 2005, pp. 41–71.
- Taub, Liba, *Ptolemy's Universe. The Natural, Philosophical, and Ethical Foundations of Ptolemy's Astronomy*, Chicago: Open Court, 1993.

- Tihon, Anne, 'Les *Tables Faciles* de Ptolémée dans les manuscrits en onciale (IX^e-X^e siècle)', *Revue d'Histoire des Textes* 22 (1992) pp. 47-87.
- Toomer, Gerald J., 'Ptolemy', in Charles C. Gillispie (ed.), *Dictionary of Scientific Biography*, vol. XI, New York: Scribner, 1975, pp. 186-206.
- Toomer, Gerald J., 'Galen on the Astronomers and Astrologers', *Archive for History of Exact Sciences* 32 (1985), pp. 193-206.
- Turner, Anthony J., *Mathematical Instruments in Antiquity and the Middle Ages*, London: Vade-Mecum Press, 1994.