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The Study of Astronomical Papyri from Neugebauer to Today

Alexander Jones

§1. Introduction

What is an astronomical papyrus? The category is not one that would have been recognized in antiquity but reflects the concerns of modern scholars. Nevertheless, the boundaries defining it in practice are reasonably clear. "Papyrus" here, as often, is a catch-all expression for any ancient writing medium that comes within the competence of a papyrologist, including papyrus *sensu stricto*, but also parchment, writing boards, and ostraca. "Astronomical" refers to the written contents—something we can see for ourselves—not the purpose, which we typically have to conjecture. If the contents primarily concern the heavenly bodies in their own right, or as they appear to an observer, the papyrus is astronomical, even if we are confident that the writer or owner was an astrologer. (Following a criterion set by Neugebauer, we exclude manuscripts of belles-lettristic astronomical poetry such as Aratus' *Phaenomena* and its commentators).[1] If the contents explicitly concern relations between the heavenly bodies and mundane conditions—individuals, peoples, and their environment—the papyrus is astrological. The status of a few kinds of text is ambiguous. Horoscopes are perhaps best treated as a category in their own right, since they present objective astronomical data associated with an individual's nativity, though few horoscopic papyri contain astrological predictions for the individual. Weather predictions derived from astronomical phenomena are usually classed as astronomy, not astrology. But the great majority of non-horoscopic papyri containing astral material can be straightforwardly designated either astronomical or astrological by these criteria, scarcely ever both.[2] The corpus is effectively limited to Hellenistic and Roman Egypt and comprises texts in both Greek (the preponderating language) and Egyptian, mostly Demotic.

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[1] Neugebauer, "Astronomical Papyri and Ostraca," *PAPS* 106/4 (1962a), 383. However, I have included such items in the Appendix to the present article.

[2] *P.Mich.* 3.149 is listed in both Neugebauer, "Astronomical Papyri and Ostraca," *PAPS* 106/4 (1962a), 383–91 and Neugebauer and van Hoesen, "Astrological Papyri and Ostraca," *PAPS* 108/2 (1964), 57–72, inventories respectively of astronomical and astrological papyri, because, although an astrological text, it has detailed passages of astronomical information though they are always subordinated to astrological interpretations. (By convention, italics indicate papyri published in monographs or series (checklist at https://library.duke.edu/papyrus/texts/clist_papyri.html) whereas Roman type indicates papyri designated by inventory numbers in public or private collections.)

The present article is in part retrospective, and serves as a complement to the essays in the recent volume, *A Mathematician's Journeys*, that explored Otto Neugebauer's contributions to the historiography of the mathematical sciences with respect to Egyptian mathematics and Babylonian mathematics and astronomy as well as the subsequent transformations of his legacy.[3] Though they account for a minuscule fraction of all surviving papyrus texts, astronomical papyri have figured in editions since the mid-19th century, beginning with Stobart's (Fig. 10.1) and Brugsch's publications of the Demotic Stobart Tablets (1855–6) and that of the Greek *P.Par.* 1 (now P.Louvre N2325), the so-called "Ars Eudoxi," by Letronne and Brunet de Presle (1865, see Fig. 10.2).[4] The starting point I will take, however, is later, with Neugebauer's initiative, only partially fulfilled, to collect and study the astronomical papyri for the first time as a distinct body of evidence for the history of ancient astronomy. In the end, an abrupt and dramatic expansion of the corpus due to the vast inventory of unpublished papyri from Grenfell and Hunt's excavations at Oxyrhynchus was what it took to reveal the main lines of astronomical activity in Greco-Roman Egypt. Following a narrative of this course of events, I will review what we learned from the Oxyrhynchus papyri and from a few other important papyri that have come to light since their publication, as well as highlighting major gaps that remain in our understanding of the Greco-Egyptian tradition.

§2. The Neugebauer-van Hoesen Collaboration

The "Notes and Correspondence" section of the March 1950 issue of the history of science journal *Isis* included the following plea:[5]

> **Greek horoscopes and astronomical texts.** The undersigned are preparing a monograph on Greek horoscopes, containing a discussion of all previously published material and the edition of unpublished texts. The authors would be very grateful for any information concerning unpublished horoscopes or texts concerning the computation of horoscopes. Magical papyri will not be included in this study.
>
> We are also interested in purely astronomical papyri like P. Lund 35 or P. Ryl. 27. A comprehensive publication concerning these astronomical texts is planned.
>
> O. Neugebauer
> H. B. Van Hoesen
>
> *Brown University,*
> *Providence, R.I., U.S.A.*

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[3] Jones, Proust, and Steele, *A Mathematician's Journeys* (2016).

[4] Stobart, *Egyptian Antiquities* (1855), which was overseen by Brugsch; Brugsch, *Nouvelles recherches* (1856); and Letronne and Brunet de Presle, *Notices et extraits des manuscrits* (1865). See also Jones, "The Place of Astronomy in Roman Egypt," *The Sciences in Greco-Roman Society* (1994b). Letronne died in 1848. Though the volume of Paris papyri completed by Brunet de Presle from his papers was published in 1865, a few scholars had earlier access to the edition of *P.Par.* 1 since material from it appeared in Wachsmuth, *Ioannis Laurentii Lydi, Liber de ostentis* (1863), 273–5 and Böckh, *Ueber die vierjährigen Sonnenkreise der Alten* (1863), 196–226.

[5] Neugebauer and van Hoesen "Notes & Correspondence: Greek horoscopes," *Isis* 41/1 (1950), 48.

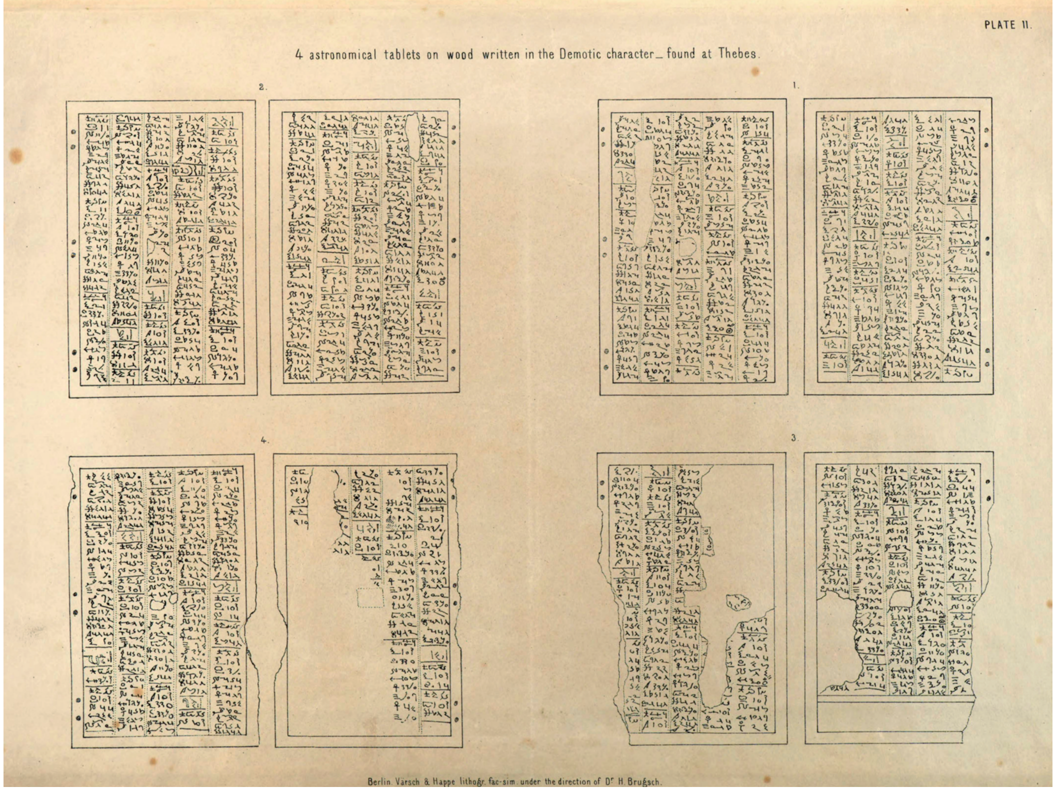

Figure 10.1. Drawings of the Stobart Tablets. From Stobart, *Egyptian Antiquities* (1855), plate II, the first publication of an archeologically recovered astronomical table from the Greco-Egyptian tradition.

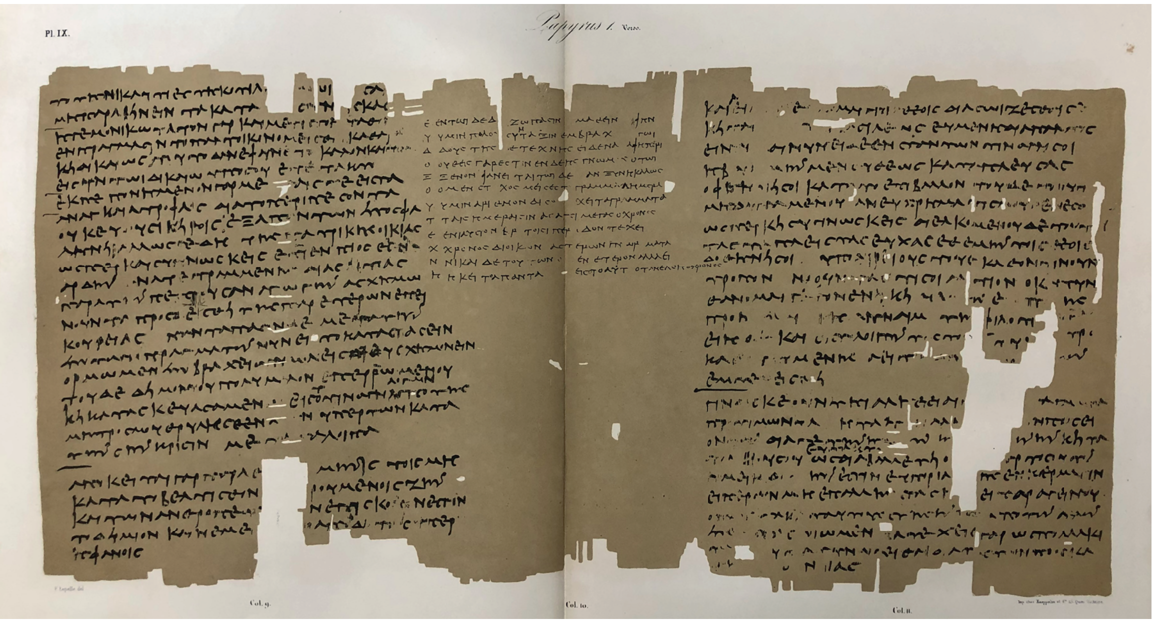

Figure 10.2. Facsimile of part of the verso of *P.Par.* 1. The acrostic verses spell ΕΥΔΟΞΟΥ ΤΕΧΝΗ, "Art of Eudoxus," in the center. From Letronne and Brunet de Presle, *Notices et extraits des manuscrits* (1865), plate IX.

This collaboration between Otto Neugebauer (1899–1990, see Fig. 10.5) and Henry Bartlett van Hoesen (1885–1965, see Fig. 10.3) resulted in their 1959 *Greek Horoscopes*, which remains after sixty years the fundamental study of the astronomical and mathematical aspects of horoscopic documents written in Greek between the 1st c. BCE and the 5th c. CE.[6] Little documentation survives that casts light on their work together. From the beginning of 1950 on, Neugebauer divided his time between Brown University and the Institute for Advanced Study in Princeton. When in Providence, his interactions with van Hoesen would presumably have been in person, but when in Princeton, they would have corresponded by mail.[7] Late in life, however, Neugebauer systematically destroyed most of his correspondence. All that I have been able to track down are three letters from Neugebauer to van Hoesen from February and March 1950, and a note on a file-card-sized slip from 1959 congratulating van Hoesen on the publication of *Greek Horoscopes* (Fig. 10.4).[8]

Van Hoesen, a Classicist, specialized in papyrology as a master's and doctoral student at Princeton between 1905 and 1912, and in his early career he wrote or contributed to various publications related to that field, including his dissertation on Roman cursive writing (published in 1915) and the first volume of the Princeton University papyri (1931); none of these had anything to do with ancient scientific texts.[9] With his appointment as Curator of Manuscripts in the Princeton University Library in 1915, however, he began a transition from papyrologist to librarian, and during two decades from 1930 to 1949 when he was Librarian of Brown University (which had no papyrus collection but was rapidly expanding and reorganizing its broad holdings) he set papyri almost entirely aside.[10] The public announcement of the joint project with Neugebauer, first in a communication presented to the Sixth International Congress of Papyrology in Paris (August 29–September 4, 1949), then in the notice in *Isis*, coincided with his retirement.[11] During the remainder of his life van Hoesen does not appear to have published anything papyrological that was not coauthored by Neugebauer.[12]

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[6] Neugebauer and van Hoesen, *Greek Horoscopes* (1959).

[7] For Neugebauer's appointments (in both the School of Mathematics and the Historical School) at the Institute for Advanced Study see https://www.ias.edu/scholars/otto-neugebauer/.

[8] For the 1950 correspondence see n. 22 below. The note, pasted in van Hoesen's copy of *Greek Horoscopes*, is among papers handed down in his family and now owned by Sally Booth-Schwadron. The address by surname and signing by initials rather than by his elephant's backside emblem (it was the same in the 1950 letters) is, for Neugebauer, on the formal side given that they had known each other for twenty years and had been collaborating for ten. In his extensive and much more intimate correspondence with E. S. Kennedy (see n. 37 below), Neugebauer never mentions van Hoesen.

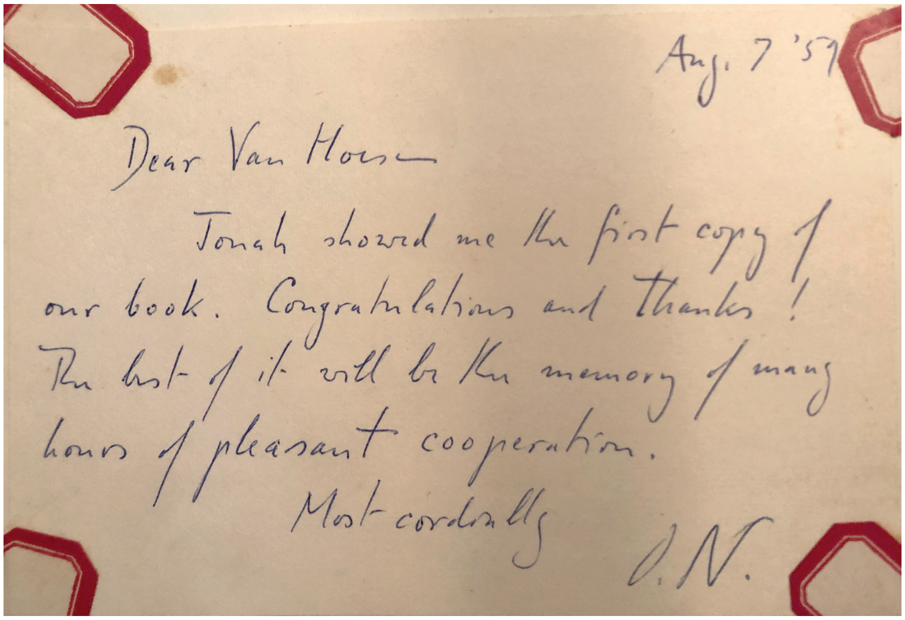
[9] Information from the Princeton University Library catalogue.

[10] *Princeton Alumni Weekly* 16/6, November 3, 1915, 1; "Special Collections of the Brown University Library: A History and Guide, Revised Web Edition: The 1930s and World War II," https://library.brown.edu/guide/08.html. In 1931 it was announced that van Hoesen was undertaking a retrospective bibliography of papyrology up to 1931 to complement the current bibliography project that became the *Bibliographie papyrologique*, but nothing came of this, Alain Martin, "75 ans de *Bibliographie Papyrologique* (1932–2007)," http://hdl.handle.net/2027/spo.7523866.0025.161. See also "A Tribute to Henry Bartlett van Hoesen upon the completion of twenty years as Librarian and Director of Brown University Library 1930–1950," *Staff Bulletin, John Hay Library, Brown University* 11/9, June 1, 1950, which includes a bibliography of van Hoesen's publications in all fields.

[11] "VI^e^ congrès international de papyrologie Paris, 29 août – 4 septembre 1949," *CdÉ* 25/49 (1950), 148–51, especially p. 151.

[12] Besides *Greek Horoscopes*, their joint publications were Neugebauer and van Hoesen, "Horoscope P. Ryl. 524," *Aegyptus* 32/2 (1952), 333–5 (a contribution to a multi-issue *Festschrift* for Girolamo Vitelli) and "Astrological Papyri and Ostraca," *PAPS* 108/2 (1964) (which will be discussed below).

Figure 10.3. H. B. van Hoesen in 1934. Photograph courtesy Sally Booth-Schwadron.



Aug. 7 '59

Dear Van Hoesen

Jonah showed me the first copy of our book. Congratulations and thanks! The best of it will be the memory of many hours of pleasant cooperation.

Most cordially

O.N.

Figure 10.4. Neugebauer's note to van Hoesen on the publication of *Greek Horoscopes*. Photograph courtesy Sally Booth-Schwadron.

Through his career, Neugebauer frequently had collaborative relationships with colleagues who could provide linguistic, philological, and paleographical skills to the study of the texts with which he was concerned. Sometimes his collaborators were themselves interested in scientific materials (Abraham Sachs for Babylonia, Richard Parker for Egypt, David Pingree for India); in other cases, they were scholars associated with papyrus collections that happened to include scientific texts (e.g., Axel Volten and H. O. Lange for P.Carlsberg, Erik Knudtzon for P.Lund, William Brashear for P.Berlin). The collaboration with van Hoesen was of a different kind, in which the motivation surely came more or less entirely from Neugebauer's side.

The announcement in *Isis* actually promised *two* publications: the monograph on horoscopes—which was presumably already intended to include both the horoscopes on papyri and other archeologically recovered media and the ones transmitted through the medieval manuscript tradition, especially those embedded in astrological treatises—and a "comprehensive publication" on astronomical papyri. The latter subject had already been conspicuous among Neugebauer's published work starting partway through his 1933–9 stay in Copenhagen. This was a period of transition for his interests: at the time he was first appointed to the faculty of the Mathematics Department of the University of Copenhagen in 1933—a position funded for three years by the Rask-Ørsted and Rockefeller Foundations and subsequently by the Carlsberg Foundation—Neugebauer was (in Harald Bohr's words) "all over the world recognized as quite outstanding as a historical mathematician." But it was during these years that he began studying the Babylonian tablets of mathematical astronomy in earnest, and only slightly later he immersed himself in Egyptian astronomy.[13] According to Neugebauer's student, Olaf Schmidt, Axel Volten had drawn his attention to the Demotic papyri P.Carlsberg 1 (which had been purchased by the Carlsberg Foundation in 1931) and P.Carlsberg 9 (purchased in 1935 and 1938) as well as the previously published Stobart Tablets (now National Museums Liverpool M11467) and P.Berlin inv. 8279, of whose existence Neugebauer had previously been unaware.[14] This was probably in 1937 or 1938.[15] His first article on a Greek astronomical papyrus also appeared in 1937.[16]

[13] Brack-Bernsen, "Otto Neugebauer's Visits," *A Mathematician's Journeys* (2016), 107–26 and Steele, "Neugebauer's Astronomical Cuneiform Texts," *A Mathematician's Journeys* (2016), 303–32. Information about the funding of Neugebauer's Copenhagen appointment, and Bohr's letter of August 18, 1933, quoted above are from Rockefeller Archive Center, Rockefeller Foundation records, projects, SG 1.1, Series 713: Denmark; Subseries 713.D: Denmark - Natural Sciences and Agriculture Box 5, Folder 58, "University of Copenhagen - Neugebauer, Otto - (Mathematics)." There are no explicit references to Neugebauer's work on Egyptian astronomy in this dossier, but a list of his grant-funded book and photograph purchases dated June 24, 1939, has 24 items of which 10 relate to Egyptian astronomy. For Neugebauer's publications up to 1979, see Sachs and Toomer, "Otto Neugebauer," *Centaurus* 22/4 (1979), which however inadvertently omits Lange and Neugebauer, *Papyrus Carlsberg No. 1* (1940).

[14] Schmidt, "Ægyptisk Astronomi," *Nordisk Astronomisk Tidsskrift* 4 (1950), 121–34.

[15] P.Carlsberg 9 was published in Neugebauer and Volten, "Untersuchungen zur antiken Astronomie IV," *Quellen und Studien* 4/4 (1938), 383–406. According to Schmidt as reported in Brack-Bernsen, "Otto Neugebauer's Visits," *A Mathematician's Journeys* (2016), 117–20, Neugebauer worked out the calendrical scheme in the papyrus within 24 hours. (Schmidt studied with Neugebauer from the mid-1930s through 1943, following him from Copenhagen to Providence where he completed his doctoral degree in Mathematics at Brown University). The edition of P.Carlsberg 1, Lange and Neugebauer, *Papyrus Carlsberg No. 1* (1940), was not quite finished by the time Neugebauer had left Denmark for the USA in 1939, and in an afterword to their joint preface Lange expresses regret that correspondence between them had become impossible on account of the war. Letters did get through, eventually, even after the book came out: about thirty from Neugebauer to Lange, variously in Danish, German, and English and dating from between December 30, 1938, and November 18, 1940, are preserved in the Royal Library, Copenhagen, and document Neugebauer's close attention to many philological details despite the obstacles his move threw in the way of his work.

[16] Neugebauer, "Zum astronomisches Papyrus-Fragment Pap. Osl. 73," *Symbolae Osloenses* 17 (1937), 49–53.

Following his move from Denmark to the United States in 1939, Neugebauer continued to publish articles on both Egyptian and Greek astronomical papyri. Most of these papyri had been published before, though where possible he procured photographs on the basis of which he frequently corrected readings; there were also a few new texts, for which he provided commentaries while a papyrologist was responsible for the edition proper, a practice that Neugebauer usually adhered to for first publications of papyri henceforth.[17] (After he left Copenhagen, he rarely studied a papyrus in person.) The planned "comprehensive publication" on astronomical papyri would thus have built upon a substantial body of previous work, and in fact the three papyri mentioned in the announcement—*P.Lund* 35 refers to two distinct fragments of tables, 35a and 35b—had already been treated extensively in published papers.

On the other hand, down to 1950 horoscopes and other astrological texts did not feature conspicuously in Neugebauer's publications, with the sole exception of a study (with reeditions and, in one instance, a first edition) of five Demotic horoscopes on ostraca.[18] He was, however, already collecting and investigating that kind of material in the early 1940s, as is evident from remarks about Greek horoscopic papyri in his articles on the Egyptian texts.[19] In a 1946 activity report to the Rockefeller Foundation he listed among his "work in progress" two projects under the subheading "Greek":[20]

> Neugebauer-VanHoesen [*sic*] "Greek Horoscopes" Edition of horoscopes from Greek papyri from the beginning of our era until the Arab conquest of Egypt.
> Neugebauer "Studies in Vettius Valens" Astronomical commentary on the astronomical sections in Vettius Valens' work on astrology, including the necessary text-critical material and translations.

(The Vettius Valens project was not realized). And two years later, the *Providence Sunday Journal* carried a full-page illustrated article on Neugebauer's researches (see Fig. 10.5), in which he is quoted:[21]

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[17] Neugebauer, "Egyptian Planetary Texts," *TAPS* 32/2 (1942a), 209–50 (reeditions of P.Berlin 8279 and Stobart Tablets, discussion of *P.Tebt.* 2.274); *idem,* "On Some Astronomical Papyri," *TAPS* 32/2 (1942b) (discussion of *P.Mich.* 3.149–51); *idem,* "Astronomical Treatise P. Ryl. 27," *Det Kongelige Danske Videnskabernes Selskab* 32/2 (1949) (discussion of *P.Ryl.* 1.27); Knudtzon and Neugebauer, "Zwei astronomische Texte," *BLund* 2 (1947), 77–88 (first editions of *P.Lund.* 35a and 35b); and Turner and Neugebauer, "Gymnasium Debts," *BJRL* 32 (1949), 80–96 (first edition of *P.Ryl.* 4.589). Many of Neugebauer's files on astronomical, astrological, and horoscopic papyri are preserved in the Papyrology Collection at the University of Michigan, Ann Arbor; additionally, several of his files on astrological papyri were given to me by David Pingree.

[18] Neugebauer, "Demotic Horoscopes," *JAOS* 63/2 (1943).

[19] In Neugebauer "Egyptian Planetary Texts," *TAPS* 32/2 (1942a), 239 and 242, he cites features of *P.Lond.* 1.130 (a deluxe horoscope for a nativity in 81 CE), while in Neugebauer, "Demotic Horoscopes," *JAOS* 63/2 (1943), 115–27, he refers (p. 122, n. 29) to *P.Lond.* 1.98 and comments at p. 119, n. 13 on the chronological range of the "approximately 50 published horoscopes on Greek papyri and ostraca," which was a reasonable tally if he was counting distinct nativity dates for papyri that contain more than one horoscope.

[20] "Project for the History of Mathematics and Astronomy in Antiquity Work in Progress 1946," typescript date-stamped April 1, 1946, Rockefeller Archive Center, Rockefeller Foundation records, projects, SG 1.2, Series 244: Rhode Island; Subseries 244 D: Rhode Island – Natural Sciences and Agriculture Box 1 Folder 7 "Brown University - Mathematics and Astronomy - (Neugebauer, Otto; Historical Studies)." This dossier concerning an exceptional out-of-program grant of $41,000 awarded to Brown University by the Rockefeller Foundation in 1943 for a ten-year term to support the research of Neugebauer and his collaborators provides the fullest records I know of for Neugebauer's scholarly hyperactivity during that decade.

[21] Spilman, "Stargazing 3000 Years Later," *Prov. Sunday Journal* (June 6, 1948), 20.

> "Here," he says, lifting out a small picture of a small papyrus fragment, "is a horoscope. Cursive Greek—and atrociously abbreviated. There are many horoscopes, but no predictions. The astrologers made no predictions."

Beyond the announcement of their twofold project at the 1949 papyrological congress and the following year in *Isis*, Neugebauer and van Hoesen approached at least a few papyrus collections and papyrologists in pursuit of new horoscopes and astronomical fragments. The three surviving letters from Neugebauer to van Hoesen document Neugebauer's visits to the Princeton University Rare Book Collection in February and March 1950, to collate the horoscope *P.Princ.* 2.75, taking advantage of the circumstance that he happened to be living in Princeton at the time.[22] In the preface to *Greek Horoscopes* they acknowledge the assistance of T. C. Skeat, Colin Roberts, and Vittorio Bartoletti for checking readings of papyri respectively in London, Oxford, and Florence, and H. C. Youtie and Jean Doresse are thanked for making available new texts (the Michigan and Louvre ones mentioned below).[23] By 1953 work had already progressed far enough that Frederick H. Cramer was able to consult a provisional typescript as he prepared his intended second volume of his *Astrology in Roman Law and Politics*.[24]

Yet the harvest was surprisingly small. In *Greek Horoscopes*, the section devoted to "Original Documents" comprises 47 horoscopic papyri, one ostracon, and one parchment quasi-codex strip, in addition to a handful of epigraphic horoscopes. Of the papyri, 43 had been previously published (one of them, *P.Oxy.* 1.307, described but not edited). The only entirely new texts were P.Mich. inv. 1461 (which Neugebauer was already studying in 1949)[25] and 6329, P.Cornell inv. 78, and the parchment Louvre 10390 (which was already in the typescript Cramer saw).[26] By 1964, when Neugebauer and van Hoesen published addenda to *Greek Horoscopes*, two more horoscopic papyri (P.Mich. inv. 6664 and P.Stras. inv. 853a) had come to their attention.[27]

The search for new astronomical papyri was more fruitful though not dramatically so: in Neugebauer's 1962 bibliographical survey of this genre (this time not coauthored by van Hoesen), out of 45 listed papyri, ostraca, and tablets, 30 had been published before 1950, six had been published since 1950 by Neugebauer with or without a coauthor, three had been published by someone else, and six were still unpublished though Neugebauer had seen photographs and worked on at least four of them.[28] Some important papyrus collections scarcely figure among

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[22] Neugebauer to van Hoesen February 14, 1950; *idem*, February 20(?) [likely 21], 1950; and *idem*, March 8, 1950 in Neugebauer's file on *P.Princ.* 2.75, University of Michigan Papyrology Collection.

[23] Neugebauer and van Hoesen, *Greek Horoscopes* (1959), vii.

[24] Cramer, "Grant No. 1396," *American Philosophical Society Yearbook* 1953 (1953), 227. Some draft chapters of the second volume (*Astrology in Roman Law and Politics in the Later Roman Empire*) are in the American Philosophical Society library in Philadelphia. Cramer died in 1954 in a car race accident in Monte Carlo.

[25] Neugebauer to H. C. Youtie December 1, 1949, in the Herbert C. and Louise C. Youtie Papers (Box 4, folder 33), Bentley Historical Library, University of Michigan, and Youtie to Neugebauer December 16–17, 1949 in the Neugebauer Papyrological Files (File P.Mich. inv. 1461), University of Michigan Papyrology Collection. In the Youtie Papers the only other correspondence with Neugebauer is from 1941, concerning the astronomical table *P.Mich.* 3.150.

[26] The "Literary Sources" section also consists entirely of texts that had been published previously at least in part.

[27] Neugebauer and van Hoesen, "Astrological Papyri and Ostraca," *PAPS* 108/2 (1964), 66–69.

[28] Neugebauer, "Astronomical Papyri and Ostraca," *PAPS* 106/4 (1962a), 383–91. Among the six unpublished fragments, *PSI* 15.1491–3 are listed with these same publication numbers given as "preliminary"; in fact, Neugebauer had already edited them for that volume, which only came out in 2008. (By that time his drafts had to be largely revised or replaced). It is curious to note that Neugebauer did not know about the important astronomical papyrus that must already have been assigned the

Figure 10.5. Neugebauer in 1948, with photographs of *P.Ryl.* 4.589 and 1.27.

the added material; conspicuously, only two non-literary astronomical papyri were published in the series *The Oxyrhynchus Papyri* after volume 3 (1903), and the motivation for editing them was pretty clearly not their astronomical contents.[29]

Non-horoscopic astrological papyri were not part of the 1949–50 call, probably because Neugebauer had little personal interest in astrology except as a source of evidence for astronomical theories and practices.[30] Nonetheless, with van Hoesen he compiled a bibliographical survey of them complementing his survey of the astronomical papyri, comprising 45 items. Six of these were as-yet-unpublished fragments that he knew about through personal communications with papyrologists.[31] No astrological papyrus, however, ever received its first publication with Neugebauer as author or coauthor.

What was the "comprehensive publication" on astronomical papyri meant to be, and why did it fall by the wayside? In approaching these questions, it is helpful to consider the role of certain comparable large-scale projects in Neugebauer's work in other fields. We can start with the "Historical Reminiscences" that he inserted in the section on the "Fundamental Patterns of [Babylonian] Planetary Theory" in his 1975 *History of Ancient Mathematical Astronomy*:[32]

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publication number 1490, and which was published provisionally in Manfredi, "Presentazione di un testo astronomico," *Atti dell' XI Congresso Internazionale di Papirologia* (1966), 237–43.

[29] *P.Oxy.* 31.2551, a regnal canon (originally edited in Sattler, *Studien aus dem Gebiet der Alten Geschichte* (1962), 39–50), and 46.3299, a sign-entry almanac notable for suppressing the name of Elegabalus. When I saw the file cards for unpublished Oxyrhynchus papyri in the 1990s (see below), a few had annotations indicating that there had been correspondence about them with Neugebauer. This must have been in the 1960s or later. The papyri in question include the horoscopes *P.Oxy. astr.* 4238 and 4246 (for both of which there are files at Ann Arbor) as well as *P.Oxy. astr.* 4168, which Neugebauer had correctly identified as Ptolemy's *Handy Tables*.

[30] Neugebauer's famous riposte to George Sarton, Neugebauer, "The Study of Wretched Subjects," *Isis* 42/2 (1951), 111, defends historical studies of astrology as yielding insights to "daily life, religion and superstition, and astronomical methods and cosmogonic ideas" and additionally for contributions to the history of philosophy and art; but his contempt for astrology in its own right is patent in such passages as Neugebauer, *A History of Ancient Mathematical Astronomy* 3 (1975), 942–3.

[31] These were published in due course as *P.Ant.* 3.141–2, *P.Oxy.* 31.2546 and 2554, and *PSI* 15.1494–95.

[32] Neugebauer, *A History of Ancient Mathematical Astronomy* 1 (1975), 431. I have omitted Neugebauer's footnotes.

> During the academic year 1933/1934 I lectured at the Mathematics Institute of the University of Copenhagen on pre-Greek mathematics. These lectures were published in a volume which was supposed to be the first in a sequence of three, the second being reserved for Greek mathematics, the third for ancient mathematical astronomy. As a preparation for the first volume, I had compiled an edition of all the mathematical cuneiform texts I could find. Being thus preoccupied with cuneiform sources I considered it economical to prepare next the section on Babylonian astronomy for the third volume. Little did I foresee that this would mean the end of the whole plan.

This succinctly recounts the origins of Neugebauer's *Mathematische Keilschrift-Texte* (1935–7) and *Astronomical Cuneiform Texts* (1955). Before one could properly investigate what was going on in an ancient scientific context, Neugebauer believed that one had to have satisfactory editions of the texts, and if there existed many texts—as was the case for Old Babylonian mathematics (in strong contrast to the other "pre-Greek" tradition covered in Neugebauer's Copenhagen lectures, Pharaonic Egyptian mathematics, which at the time was represented by just two major papyri and a handful of small fragments)—a comprehensive edition employing uniform editorial practices and so organized as to allow related texts to illuminate each other was a desideratum. For Babylonian mathematics, the available editions in the late 1920s when Neugebauer began working on the subject were few and marred by very deficient understanding of the character and language of the texts, so that *Mathematische Keilschrift-Texte* was practically the first usable resource.[33] In contrast, Joseph Epping, Johann Nepomuk Strassmaier, Franz Xaver Kugler, François Thureau-Dangin, and Paul Schnabel had built up a mostly impressive body of scholarship on Late Babylonian mathematical astronomy incorporating many good text editions dispersed rather chaotically through several publications.[34] Expecting initially that he had little more to do than to collect these texts in a more compendious arrangement, Neugebauer eventually spent much of two decades reorganizing the corpus by means of powerful methods of mathematical analysis, all the while incorporating substantial bodies of newly discovered tablets.[35] *Astronomical Cuneiform Texts* proved to be a model of how an edition could elucidate and demonstrate the coherence of a scientific text corpus.

A typescript report that Neugebauer wrote in 1951 or 1952 on "recent work in the history of mathematics and astronomy" reveals both the breadth of his activities around this time and a tendency on his part to seriously underestimate how much time would be needed to bring his various editions-in-progress to completion.[36] Besides many more modest undertakings, he

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[33] Neugebauer, *Mathematische Keilschrift-Texte* (1935–7); Høyrup, "As the Outsider Walked in," *A Mathematician's Journeys* (2016), 165–95.

[34] de Jong, "Babylonian Astronomy 1880–1950," *A Mathematician's Journeys* (2016), 265–302.

[35] Neugebauer, *Astronomical Cuneiform Texts* (1955); Steele, "Neugebauer's Astronomical Cuneiform Texts," *A Mathematician's Journeys* (2016), 303–32.

[36] "Report by O. Neugebauer on Recent Work in the History of Mathematics and Astronomy," Richard Courant Papers (New York University Archives) Box 17, File "NEUGEBAUER, O. 1938–1953." This is likely to be a carbon copy of a report to the Rockefeller Foundation for a $41,000 grant awarded to him in 1943 for a ten-year research program on "history of ancient mathematics and astronomy" (see Rockefeller Foundation *Annual Report* 1943, 166–7).

lists not only *Astronomical Cuneiform Texts*, anticipating completion in 1953, and the Greek horoscopes volume "to be completed within two years," but also an edition with Richard Parker of "all available [Egyptian] astronomical texts on coffins and papyri and monuments in tombs and temples." He writes that this last project was begun already in 1945 and would be finished "in about two years"; it would be 1960 when the first volume of *Egyptian Astronomical Texts* was eventually published, with the third and final volume coming out only in 1969. That *Greek Horoscopes* took four years longer than Neugebauer expected is hardly surprising.

Let us look more closely at what *Greek Horoscopes* did for the horoscopic texts. The core of *Greek Horoscopes* is the presentation of the horoscopic texts themselves, in two parts containing respectively the "original," i.e., archeologically recovered horoscopes (mostly papyri) and the "literary" horoscopes, i.e., those preserved in medieval manuscript copies. In both sections, each horoscope is presented as an individual item, with an identifier incorporating the date to which it refers, or, if that could not be determined, an estimated date. For example, "No. 217" is one of four horoscopes in the papyrus *P.Warren* 21, which does not state its nativity date but has astronomical data fitting May 12 or 13, 217 CE; "No. 250,2" is a fragmentary deluxe horoscope in *P.Ryl.* 3.524, not datable from its contents but estimated to belong to the 3rd c. CE by paleography; and "No. L 75"—L indicating "literary"—is a horoscope presented in three quite different versions in Books 3 and 4 of Vettius Valens' *Anthologiae*. Thus, the horoscopes have been abstracted from their original contexts (whether we are speaking of an artifact such as a particular papyrus fragment or a particular passage of an extended text). In Neugebauer and van Hoesen's system, all text and data referring to a single date and time associated with a specific individual's birth or some other event constitutes a distinct horoscope, even if we have multiple sources, say two horoscopes on papyri calculated by different astrologers for the same client, or two passages of Vettius Valens discussing different astrological issues with reference to the nativity of the same unnamed person. Except for the division into "original" and "literary," the horoscopes are presented simply in chronological order. Obviously, this plan is most conducive to research that treats horoscopes generically, seeking patterns and trends in the astrological tradition as a whole.

For each "original" horoscope, Neugebauer and van Hoesen begin with a reedited Greek text (unless the papyrus was lost) and English translation, whereas they provide only translations accompanied by textual notes for the "literary" horoscopes. Then comes an astronomical commentary, which has two functions:

> (i) If a horoscope is missing all or part of the date to which it refers, or the date has some ambiguity, then the precise date is determined, or a range of more or less acceptable dates is found, on the basis of the astronomical data in the text.
> (ii) The astronomical data in the text are compared for accuracy with data computed by Neugebauer for the date in question using modern astronomical tables.

Astrological commentary tends to be limited to discussions of technical methods such as the calculation of astrologically significant points of the zodiac that depend on the astronomical data.

The collection of horoscopes is preceded by a brief explanation of the methods Neugebauer used to date the horoscopes that lack an explicit date, and an extensive glossary *raisonné* of technical (astronomical, chronological, and astrological) terminology. Following the horoscopes are two discursive chapters. The second of these concerns just the "literary" horoscopes and consists of discussions about distinctive aspects of the horoscopes extracted from or attributed to individual authors; this serves to counterbalance the chronological presentation of the texts. The first, however, is a synoptic treatment of all the horoscopes, surveying topics such as chronological distribution, terminology, patterns of arrangement of the data, chronological practices, and the astronomical and astrological data. A central concern for Neugebauer was the extent to which one could recover the astronomical methods and resources employed by astrologers to compute the horoscopes. The outcomes were, for him, disappointing. As he wrote to E. S. Kennedy four years before the book was finished and published:[37]

> It is a hell of a work, actually for very little results.

Few of the horoscopes refer to tables or other resources, and the references that exist are brief and unexplanatory. Moreover, the precision of most of the horoscopes is very coarse, typically indicating locations of heavenly bodies and astrologically significant points only by the sign of the zodiac without numbers of degrees, so that few clues (such as characteristic patterns of errors) remain in the data to indicate how they were obtained.

Neugebauer was an industrious calculator with pencil and paper, and although he stresses that one only needs quite unsophisticated, rough-and-ready graphical methods to carry out the first stages of dating horoscopes, all the final computations of solar, lunar, and planetary positions according to modern theory were done by hand using the early 20th century tables of P. V. Neugebauer.[38] (It was a few years later that Bryant Tuckerman programmed an IBM computer at Neugebauer's behest to compute tables of the positions of the heavenly bodies at five and ten day intervals from the 6th c. BCE to the time of Kepler). Despite the crudeness of most of the ancient data, Neugebauer was able at least to obtain a rough estimate of the deviation of the ancient frame of reference for zodiacal longitudes from the modern tropical frame of reference.[39] His ability to compare data in the horoscopes with extant ancient astronomical tables was practically limited to the horoscopes in Vettius Valens, many of which overlap the range of dates covered by the Stobart Tablets. Although he suspected—correctly—that some of the latest (5th c. CE) horoscopes were based on the tables of Ptolemy's *Almagest* or the *Handy Tables*, his endurance apparently did not extend to repeating those calculations.

Restricting our consideration to the horoscopes on papyrus and other "original" media, in what ways did *Greek Horoscopes* advance on what was available before? First, there were the horoscopes, modest in number, that had not previously been published or had only received partial editions or just descriptions, and in addition a scattering of corrections to the

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[37] Neugebauer to Kennedy, September 6, 1955, E. S. Kennedy Correspondence 1950–65, Box 13, Otto Neugebauer Papers, Shelby White and Leon Levy Archives Center, Institute for Advanced Study, Princeton.

[38] Neugebauer and van Hoesen, *Greek Horoscopes* (1959), 1–2. The two Neugebauers were not related.

[39] Neugebauer and van Hoesen, *Greek Horoscopes* (1959), 171–2.

readings of earlier editions. Secondly, in addition to the obvious convenience of simply having the texts of all the known horoscopic papyri in one place, the fact that they were all now translated in a consistent way made them accessible to historians who had little or no Greek or who lacked a papyrological library. Thirdly, the horoscopes received a uniform, competent level of astronomical analysis and commentary for the first time, so that questions concerning the astronomical and computational qualifications of ancient astrologers could be approached with a broad base of evidence. And finally, although Neugebauer and van Hoesen paid little attention to non-scientific (e.g., linguistic or social) aspects of their material, *Greek Horoscopes* made the existence and potential interest of the horoscopic papyri more visible to scholars in other disciplines.

If in 1962, instead of a bibliographical survey of astronomical papyri, Neugebauer had published a monograph centering on editions or reeditions of the 45 items (both Greek and Egyptian) listed in that survey, it would have had a quite different character from *Greek Horoscopes*. The horoscopes are essentially variations of a single kind of entity, defined by a set of stated longitudes of the Sun, Moon, planets, and astrologically significant points (at minimum the *horoskopos* or point of the zodiac crossing the eastern horizon) computed for a particular date, time, and locality. The astronomical papyri have no such obvious unity. Twenty-nine of Neugebauer's 45, nearly two-thirds, are tables, and of these, 15, a little over half, were (or appeared to Neugebauer to be) tabulations of positions of one or more heavenly bodies on a series of specific dates. These almanac-like tables were themselves quite diverse in content and arrangement, with only two readily identifiable subgroups sharing a common format: tables of dates when each of the planets was calculated to cross from one zodiacal sign to a neighboring sign (P.Berlin inv. 8279, Bodl. MS. Gr. Class. F 7, Stobart Tablets, and "probably" P.Stras. inv. 1097), and "ephemerides" in the strict sense that tabulated longitudes of heavenly bodies at one-day intervals in a calendrical framework (*P.Harris* 1.60, P.Mich. inv. 1454, "probably" *P.Ryl.* 3.526, *P.Tebt.* 2.449, and P.Vind. inv. 29370 and 29370b).[40]

Among the 14 non-almanac tables, a rather loosely defined and only indirectly astronomical subgroup, comprised chronological tabulations (two regnal canons, *P.Oxy.* 1.35 and 31.2551, and one calendar concordance, P.Iand. inv. 654).[41] Three tables (P.Carlsberg 32 and *PSI* 15.1492–3) were patterns—Neugebauer called them "auxiliary tables" or "templates"—of the day-by-day motion of a single heavenly body, respectively Mercury, Saturn, and the Moon, not associated to specific dates but describing a repeating cycle. Two (P.Lond. 1278 and *P.Ryl.* 3.522–3) were from sets of tables related to Ptolemy's *Almagest* and *Handy Tables*. Among the remainder no two appeared to be alike, and for the most part Neugebauer was unable to identify them.

The non-tabular papyri ("texts") had hardly anything in common with one another beyond being concerned with astronomy in one way or another. While the tables were all from the

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[40] As will be noted below, P.Stras. inv. 1097, which remained unpublished until 2018 (Jones, "P.Stras. inv. 1097," *ZPE* 207 (2018a), 179–88), turns out not to be a planetary almanac. The nature of *P.Ryl.* 3.526, beyond that it is definitely an astronomical table, remains unknown.

[41] *P.Oxy.* 31.2551, a fragment of a codex leaf or bifolium, has traces of astronomical text of unknown character accompanying the regnal canon. I see no reason to assume that the other two papyri were intended for astronomical uses.

Roman Period (late 1st c. BCE on), the texts included some substantial Hellenistic examples (*P.Hib.* 1.27 and P.Vind. Inst. f. Österr. Geschichtsforschung from the early 3rd c. BCE, *P.Ryl.* 4.589 = inv. 666 and *P.Par.* 1 from the 2nd c. BCE), and these generally concerned topics typical of earlier Greek astronomy, such as calendar cycles, *parapegmas*, and weather prognostication. Neugebauer loosely applied the term "treatise" to many of the "text" papyri, but most of the Roman Period fragments are too slight to allow a definite identification of genre.

A critical exception to this picture of the astronomical papyri as a rather disjointed corpus of material is a cluster connected directly or indirectly with the "text" papyrus *P.Ryl.* 1.27. In a paper devoted to that papyrus, Neugebauer had shown that it constituted a set of instructions (what in the context of Babylonian astronomy he would have called a "procedure text") for generating a table of lunar longitudes for specific dates at intervals of 248 and occasionally 303 days, precisely the kind of table of lunar longitudes that he had identified in *P.Lund* 35a shortly before.[42] Complementarily, *PSI* 15.1493 tabulated a repeatable cycle of 248 consecutive days of lunar motion, modelled as an arithmetical pattern called a linear zigzag function, by means of which one could calculate lunar longitudes for any date by adding a quantity read off from this table to a quantity read off for a preceding date from a table like *P.Lund* 35a. Neugebauer pointed out that both the principle of the linear zigzag function and the 248-day cycle originated in Babylonian astronomy; and similarly, the planetary patterns of daily motion in P.Carlsberg 32 and *PSI* 15.1492 could be paralleled in Babylonian tablets.

The Rylands and Lund papyri are precisely the ones given in their 1950 announcement as examples of the kind of thing Neugebauer and van Hoesen were looking for. It seems obvious, therefore, that Neugebauer hoped to find more of this kind of connective relation through new texts, and to some extent this happened, since he certainly did not know about the *PSI* tables (and probably not P.Carlsberg 32 either) as early as 1950. I would guess, however, that by the time *Greek Horoscopes* was completed, he concluded that there was still not enough cohesion among the astronomical papyri to make a comprehensive monograph an attractive project. Eventually he did collaborate with Parker on a collective edition of the Demotic papyri in the last volume of *Egyptian Astronomical Texts*.[43] For the rest, one only has the comments on astronomical papyri scattered through the second volume of the *History of Ancient Mathematical Astronomy* and a string of papers devoted to newly discovered papyri that papyrologists brought to his attention right through the late 1980s.

§3. HISTORICAL REMINISCENCES

One of the first classes that I had as a doctoral student in the History of Mathematics Department at Brown University in 1981–2 was with Gerald Toomer, reading Ptolemy's *Almagest* over two semesters. The class was exceptionally large by the department's standards, for in addition to me, Takao Hayashi (who was studying with David Pingree) and Michio Yano (then visit-

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[42] Neugebauer, "The Astronomical Treatise P. Ryl. 27," *Det Kongelige Danske Videnskabernes Selskab* 32/2 (1949); Knudtzon and Neugebauer, "Zwei astronomische Texte," *BLund* 2 (1947), 77–88.

[43] Neugebauer and Parker, *Egyptian Astronomical Texts* 3/1 (1969).

ing the department) sat in on most of the sessions, though I had the regular duty of rendering Ptolemy's Greek aloud and fumbling to explain what I thought he was up to.[44] In preparing his translation of the *Almagest*, which he was seeing through the press, Toomer had noticed a number in Ptolemy's report of one of Hipparchus' observations that he realized represented a day count in 248-day cycles of the variation in the Moon's apparent speed, and my first major research assignment for the class was to survey the cross-cultural evidence for this 248-day parameter. This was a lucky topic, because I was able to tie up some loose ends in Neugebauer's treatment of the relevant cuneiform and papyrological material, and, anything but offended, Neugebauer generously handed over to me his files of photographs, notes, and correspondence on the three important *PSI* volume 15 papyri that were still "in press" after a quarter-century.[45] This was the start of my engagement with astronomical papyri, which for several years afterwards was primarily a matter of filling in gaps in Neugebauer's work.

With respect to Neugebauer's own contributions to this field, the best was to come last. Marvin L. Colker (1927–2020), a Classicist at the University of Virginia and specialist in medieval Latin paleography, had acquired a papyrus fragment whose contents he wanted to have identified.[46] The front bore parts of a few lines of practically illegible cursive, but on the back were columns of Greek numerals that no one Colker asked could explain. Eventually a photograph got to Neugebauer, who recognized to his great astonishment that one column of numbers was a sequence of values of the lengths of consecutive lunar months computed according to precisely the same algorithms that were used in one of the most complex parts of Babylonian mathematical astronomy, the so-called Lunar System B. Neugebauer had always downplayed the extent to which the more advanced parts of Babylonian astronomy had been transmitted into the Greek-speaking world, and here was a papyrus that could for all intents and purposes have been an exact transliteration of one of the twenty-column cuneiform tables that he had edited in *Astronomical Cuneiform Texts*.[47]

At some point around 1990, the mathematician and historian of mathematics David H. Fowler (1937–2004), who had taken an interest in so-called fraction tables in Greek papyri, told me that upon a visit to the Papyrology Rooms (then in the Ashmolean Museum), he had been shown part of the file card catalogue of unpublished Oxyrhynchus papyri belonging to the Egypt Exploration Society, and that he noticed that there were a fair number classified as astronomy—which was unexpected, since of the close to 4000 papyri published up to then in the *Oxyrhynchus Papyri* series, only four or five were astronomical. Notwithstanding the reputation the keepers of the Egypt Exploration Society papyri had for being somewhat less than welcoming to outsiders' inquiries about their unpublished holdings, on a brief visit I paid to Oxford in

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[44] This was, I believe, the first time since it was founded in 1947 that there were two graduate students simultaneously in the History of Mathematics Department. In Neugebauer's elaborate system of nicknames, the current student, if there was one, was "SB" (for "Student Body"). I was therefore "SB2."

[45] Eventually my paper evolved into Jones, "The Development and Transmission of 248-day Schemes for Lunar Motion," *AHES* 29 (1983), 1–36. The files in question are now in the University of Michigan collection.

[46] See Jones, "A Greek Papyrus," *ZPE* 119 (1997a), 167; the papyrus was listed in European sales catalogues in 1949 and 1964.

[47] Neugebauer, "A Babylonian Lunar Ephemeris," *A Scientific Humanist* (Fs Sachs) (1988), 301–4 and, for his setting of this discovery in a context of more than two millennia of astronomical tradition, Neugebauer, "From Assyriology to Renaissance Art," *PAPS* 133/3 (1989), 391–403.

early 1991 John Rea showed me the drawers of file cards—there were easily a couple of inches of cards filed as "astronomy," about the same again as "astrology," as well as many "horoscopes"—and having gone through some of them together, we picked out a few items that looked promising enough from the short, handwritten descriptions to be worth pulling out photographs. In the end, we chose seven fragments or sets of fragments that day, all of them tables, to see what I could do with them.[48] After three intense sojourns in Oxford between 1992 and 1996 (fueled by untold quantities of Revel Coles' coffee and ginger flapjacks),[49] the number of items finally included in my *Astronomical Papyri from Oxyrhynchus* was 193: 16 theoretical and procedure texts, 108 tables, and 69 horoscopic papyri.

The form the edition took deserves some explanation. The general policy of the Egypt Exploration Society was that papyri from Grenfell and Hunt's excavations should only be published in the series *The Oxyrhynchus Papyri*.[50] By 1994, however, with well over a hundred publication-worthy astronomical papyri and horoscopes identified and already in an advanced state of preparation, it was clear that my edition would have to take the form of a comprehensive monograph, rather than little groups of texts distributed over successive volumes of *P.Oxy.*; but the editors of the series told me in all seriousness that they were afraid that a volume devoted wholly to this kind of material would provoke many E.E.S. Graeco-Roman members to cancel their subscriptions. We agreed therefore that this particular set of papyri would be published outside the series, but with regular *P.Oxy.* numbers 4133–4300 assigned to them and a list of the papyri to be included in the forthcoming series volume 61 in their expected place. (Papyri selected for inclusion after these numbers were reserved were given numbers with appended letters like 4196a but were not listed in vol. 61). A benefit of this compromise was that it was possible to present the papyri with text and translation *en regard* and commentaries in a separate volume, a layout that is much more convenient for scientific texts than the *P.Oxy.* format, with translation (often selective) in small type following the text, that goes back to Grenfell and Hunt.[51]

Astronomical Papyri from Oxyrhynchus did not constitute by any means the entirety of the astronomical and horoscopic fragments in the Oxyrhynchus collection in Oxford. To make it clearer what the edition *does* include, I have to explain how the collection was disposed in the 1990s in a little more depth than I did in my introduction to the book.[52] The unpublished papyri were stored in two series of boxes: a "main series" of more than 120 consecutively numbered

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[48] This initial sampling fortuitously turned out to include examples of most of the recurring types of table discussed in the next section of this paper: an ephemeris (*P.Oxy. astr.* 4179), a sign-entry almanac (4196a), five-day almanacs (4206, 4208, 4211, and part of 4212), an epoch table (4148), templates (4162, 4166, and 4217b), and *Handy Tables* (4168 and parts of 4167 and 4173a).

[49] See West, *Homeri Ilias I* (1998), xxxvii.

[50] There have been exceptions, notably Zilliacus et al., *Fifty Oxyrhynchus Papyri* (1979); even among the few astronomical papyri published before 1999, *P.Oxy.* 31.2551 was previously published under its inventory number in Sattler, *Studien aus dem Gebiet der alten Geschichte* (1962).

[51] The convenience was somewhat diminished by the publisher's decision to bind the two volumes as one. The disappointing print quality and limited quantity of photographs of the papyri at the end of volume 2 is now mitigated by the availability of good color images on the "POxy: Oxyrhynchus Online" website (http://www.papyrology.ox.ac.uk/POxy/), though regrettably these still do not include images of sides of the papyri that do not bear the edited texts.

[52] Jones, *Astronomical Papyri from Oxyrhynchus* 1 (1999a), 56–57.

boxes, and several hundred so-called "scrap boxes."[53] Within each main-series box were hundreds, even thousands, of papyrus fragments layered in loose sheets of the Oxford Gazette (a space-efficient method, and apparently quite safe from long-term damage to the papyri), indiscriminately with respect to genre; the order is a complicated and to some extent unfathomable outcome of undocumented processes of sorting during roughly the first half of the 20th century.[54] Either individually or in sets that may rise to hundreds of tiny fragments, the papyri have been assigned inventory numbers that begin with the box number followed by a designation of the layer, following conventions that vary from box to box, but that in principle allow one to locate any fragment from its inventory number. Over several years starting in the mid-1960s, the fragments in most of the main-series boxes were systematically catalogued on file cards, with one set of file cards organized by inventory number and another set of duplicates organized by genre. What was written on a card could be anything from a partial transcription and comment on the hand to a terse and uninformative description (e.g., "65 small fragments in literary and documentary hands"). For the majority of the boxes, a set of black-and-white photographs of the fragments and corresponding file cards were stored in a companion box.

My search for astronomical papyri thus necessarily started with the card file, followed by inspection of the corresponding photograph to see if the indexed fragments were worth further study. It quickly became apparent that the cataloguing had been in some respects inexact and in others remarkably thorough. The papyrologists who had written the cards were deeply experienced across the range of genres of literary and documentary papyri, but of course less so in the ancient scientific traditions, and with so many thousands of pieces to inventory, identifications of genre had to be made in short order. Hence some fragments filed as astronomical turned out to be horoscopes or other kinds of astrological or mathematical texts, while conversely the cards for astrology, mathematics, and "calculations" included a good number of astronomical items. This was sometimes obvious from partial transcriptions on the cards themselves, but often only became apparent when one looked at the photographs. An early decision was to include horoscopes—even very poorly preserved ones—as a category of astronomical papyri, since they record computed positions of heavenly bodies, but to exclude all other astrological texts. On the other hand, the cards frequently led to nothing more than tiny fragments of tables preserving only one or two numerals or just some vestiges of tabular ruling. It was hard to imagine any scholarly value in editing such scraps, so they were left out.

The distribution of papyri in the boxes is by no means random. Most boxes contain fragments excavated during a particular campaign of the six that Grenfell and Hunt carried out

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[53] The highest box number that I know of is 127. Not quite all the numbered boxes are from Oxyrhynchus; for example, Box 79 turned out to contain papyri from Grenfell and Hunt's campaign at Tebtunis and has been transferred to Berkeley to rejoin the rest of that collection; see Jones, "More Astronomical Tables from Tebtunis," *ZPE* 136 (2001), 211–20 and Maclay, "Tebtunis Papyri Returned," *UCBerkeleyNews* (October 18, 2005), https://www.berkeley.edu/news/media/releases/2005/10/18_tebtunis.shtml.

[54] Turner, "Edgar Lobel †," *Gnomon* 55/3 (1983) provides some traces of the collection's history in the period following Hunt's death in 1934, from which it appears that the main series boxes already existed by then. It is often said that the collection comprises about half a million fragments (e.g., Parsons, *City of the Sharp-Nosed Fish* (2007), 17). I am not sure how this was calculated. It is hard to imagine any practical way of counting them, aside from the question of what constitutes a countable papyrus in a collection of items ranging from a few intact rolls to mere dust, but I would guess that by any reasonable definition the half-million figure is an underestimate.

between 1896/7 and 1906/7, and numbered packets of layers of papyri tend to correspond to the original tin boxes in which the papyri were packed on discovery. It proved worthwhile, therefore, to check the photographs of nearby layers for additional, imperfectly inventoried fragments of a publishable text. Eventually, I had the opportunity to scan rapidly right through most of the photograph boxes, specifically looking for tables, which are usually easy to recognize at a glance. The circumstance that several tables turned up at that late stage that could never have been located from file cards suggests that there must also remain some unidentified "text" fragments.[55] As it is, four important papyri (two texts, one table, one horoscope) came to my attention too late to include.[56]

The scrap boxes remain largely a *terra incognita*. They were neither photographed nor were they inventoried with anything like the thoroughness given to the main series, and in the 1990s the majority were inaccessibly in offsite storage in Nuneham Courtenay. Occasionally a file card referred to a fragment in a scrap box, and if that box was in the malodorous basement of the Ashmolean, it was possible to inspect the papyrus, and some made it into the volume. I have records from index cards of more than twenty items in scrap boxes identified as astronomy, tables, or horoscopes that I was unable to see; some of these would probably turn out on examination to be negligible but probably not all, and they are doubtless only a small fraction of the astronomical papyri lurking in the scrap boxes.

§4. CRITICAL MASSES

We can distinguish between two kinds of order-giving cohesiveness that Neugebauer had succeeded in establishing among certain groups among the astronomical papyri. On the one hand, multiple texts could share a common format determining both the varieties of data they contain and their arrangement. This was the situation with the planetary almanacs P.Berlin inv. 8279 and the Stobart Tablets. On the other hand, texts differing in format could be components or products of a single "system" representing, say, a common theory or unified set of predictive methods. The interconnections among *P.Ryl.* 1.27, *P.Lund* 35a, and *PSI* 15.1493 were of this kind, since they all pertain, though in different ways, to a coherent set of arithmetical algorithms and tables for computing positions of the Moon.

While common formats only need a few decently preserved examples to be recognized, relations among texts that subsist at the level of a common underlying system can typically be detected only through mathematical (and occasionally also terminological) analysis of texts that are reasonably well preserved and that contain quantitative data expressed to some degree of precision. The lunar longitudes in *P.Lund* 35a, for example, are expressed to the full preci-

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[55] To take a single example, *P.Oxy. astr.* 4164a, a "template" table of the Moon's day-by-day motion, was described on its card as an account in artabas, because the symbol representing artabas is identical to the notation representing zero in Greek astronomical texts.

[56] These fragments, which it is hoped will be published in due course in the *Oxyrhynchus Papyri* series, are two instruction manuals for Ptolemy's *Handy Tables* (one of them, containing a worked example for 215 CE, had been inventoried as mathematics), a table of longitudes of conjunctions computed by the Babylonian lunar System B (see Jones, "Babylonian Lunar Theory," *Under One Sky* (2002)), and a deluxe horoscope in tabular format.

sion (three fractional sexagesimal places) with which they had been calculated, and there are enough of them surviving to show the pattern, while the procedure text in *P.Ryl.* 1.27 is preserved almost in its entirety. The tabulated quantities in *PSI* 15.1493, however, are rounded or truncated to one fractional sexagesimal place, so that while the fact that this table was derived from linear zigzag functions is readily demonstrable, Neugebauer was not able to determine the exact values of the defining parameters.

The textbook illustration of a successful establishment of a typology of text formats in an ancient astronomical tradition is Sachs' 1948 classification of the non-tabular Babylonian astronomical tablets.[57] When he wrote this paper, Sachs knew just 39 non-tabular Babylonian cuneiform texts, among which he identified recurring formats that he named Almanacs (14 examples); NS (Normal Star) Almanacs (13); Goal-Year Texts (7); and Diaries (7).[58] These types accounted for all but two of the tablets. When Sachs gained access to many hundreds of additional tablets in the British Museum over the following seven years or so, most of the non-tabular texts could still be classified into these four types, in addition to which a fifth type, Excerpts, was now discernable.[59] (One of the two unclassified texts in 1948 was in fact an Excerpt text.) Thus, the Babylonian astronomical archives possessed a limited range and coherence of standard text types such that fewer than forty known texts constituted a "critical mass" sufficing to establish a large part of the pattern.

In 1962, the year of Neugebauer's bibliographical inventory of astronomical papyri, the corpus might have appeared to be on the verge of becoming a critical mass with respect to tables (not non-tabular texts as with Sachs' cuneiform material), with three formats recurring, though the numbers were still fairly small. The pace of discovery of new papyri, however, was slow, averaging less than one a year between 1962 and 1988, and many of these were small fragments. Access to the papyri from Oxyrhynchus, which roughly tripled the number of known astronomical papyri, resulted in the recognition of several recurring formats of tables in addition to the three previously recognized formats. (Even during the long pre-publication embargo on discussing the new Oxyrhynchus material, I was able to revise the classification of several previously published papyri in the light of this expanded typology.) The following are the tabular formats known by 1999, with in parentheses the number of examples in Neugebauer's 1962 survey, the number that came to light between 1962 and 1999 excluding those in *Astronomical Papyri from Oxyrhynchus*, and the number edited in that work:[60]

> (1) *Sign-entry almanacs* (3, 4, 16). These are the planetary almanacs of the Stobart Tablets type that list computed dates, covering an interval of several years, when each of the five planets crosses from one zodiacal sign to a neighboring

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[57] Sachs, "A Classification of the Babylonian Astronomical Texts," *JCS* 2/4 (1948), 271–90. Strictly speaking, the classification concerned only those non-tabular texts that were not procedure texts explicitly connected with the tablets of mathematical astronomy.

[58] 37 tablets are listed in his Table 1 (pp. 275–6) and two additional small fragments of Diaries on p. 285.

[59] See the categorized list of tablets in Sachs, *Late Babylonian Astronomical and Related Texts* (1955), x–xxxviii (not yet superseded in print). Excerpt texts are listed there as "Planetary and Lunar Observations, etc."

[60] Jones, *Astronomical Papyri from Oxyrhynchus* 1 (1999a), 35–46; Jones, "A Classification of Astronomical Tables on Papyrus," *Ancient Astronomy* (1999b).

sign. In some Sign-entry almanacs there are also occasional computed dates of other phenomena of the planets such as first visibilities or stations.

(2) *Monthly almanacs* (2, 3, 6). These planetary almanacs pertain to a single planet or all five. For each calendar month of a series of years, the planet's longitude (either precise, in degrees, or just the zodiacal sign) is tabulated for at least one date, which may be a sign-entry or another planetary phenomenon or simply the first day of the month.

(3) *Five-day almanacs* (1, 0, 10). These planetary almanacs tabulate, for the five planets, each planet's computed longitude at constant intervals of five days.

(4) *Ephemerides* (3, 3, 9).[61] These tabulate the computed longitudes of the Sun, Moon, and planets for each day of each calendar month of one or more successive years.

(5) *Almanac-ephemerides* (1, 0, 3). These are a combination of monthly almanac for the planets and ephemeris for the Moon.

(6) *Epoch tables* (1, 0, 19). These tabulate, for a single heavenly body (Sun, Moon, or planet), dates and computed longitudes for successive occurrences of a particular phenomenon.

(7) *Templates* (3, 1, 10). These tabulate a heavenly body's computed progress in longitude on successive days starting from a particular phenomenon.

(8) *Mean motion tables* (1, 0, 4). These tabulate quantities that increase in proportion to elapsed time in units of hours, days, calendar months, and years; the quantities are to be understood as angular positions of component circular motions in a theoretical model for a heavenly body's motions.

(9) *Anomaly tables* (0, 0, 6[62]). These tables correlate mean motions in a theoretical model for a heavenly body with quantities from which the body's longitude can be calculated.

(10) *Tables of ascensions* (2, 0, 2). These tables correlate degrees of the zodiac with degrees of the celestial equator that cross the horizon or meridian simultaneously.

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[61] I count as ephemerides four examples that are not sufficiently preserved to decide whether they are pure ephemerides or almanac-ephemerides.

[62] The identification of two of these as anomaly tables is not certain.

There are also tables that do not fall in any of these categories. A few are one-offs of identifiable contents (e.g., declinations, equation of time, parallax) such that we would surely find other examples if the corpus was sufficiently bigger; others elude identification so that it is difficult to say whether they represent standard, if comparatively uncommon, types. It seems clear, however, that the great majority of astronomical tables written on papyrus conformed to one or another of a range of formats that were not much more than ten in number. They constituted the astronomical toolbox of the astrologers of Greco-Roman Egypt.

A large fraction of the papyrus tables is datable by their contents; with rare exceptions, we can assume that tables were either retrospective by at most a few decades or roughly contemporary with the phenomena they record, since the astrologers who used them were mostly interested in past dates going back no more than a lifespan. With the exception of the more or less tabular layout of a calendrical scheme in the early 2nd c. BCE *P.Ryl.* 4.589, the earliest astronomical tables on papyrus are not older than the last decades of the 1st c. BCE, and the latest are from the 5th c. CE, with the peak of activity, both in terms of numbers of papyri and variety of formats, in the 2nd through 4th centuries.

The Oxyrhynchus material augmented the corpus of non-tabular astronomical texts (13 in Neugebauer's 1962 list, 11 between 1962 and 1999) by only 16 papyri, proportionately a much smaller increase than for tables (or for horoscopes, for that matter). I suspect that a major cause of this difference is that small tabular fragments are easier to recognize as astronomical than small fragments of prose. In surveying a small collection of papyri, a papyrologist is more likely to be able to devote the attention to smaller fragments that is needed to determine their genre, whereas in the vast collection of the unpublished Oxyrhynchus Papyri it would be much easier for a fragment of astronomy to go unnoticed unless it was well enough preserved to exhibit rather obvious terminology. Most of the 16 new texts are indeed comparatively substantial pieces.

Such as it is, the known body of non-tabular texts is not characterized by well-defined formats comparable to the recurring formats among the tabular papyri or the Babylonian non-tabular texts. Where such formats are apparent, they tend to be means of presenting assemblages of homogeneous data, and they are defined first by the selection of data to be recorded and secondly by the structure or arrangement. A few of the astronomical texts in the papyri too are essentially data and evidently represent recurring formats despite the scarcity of extant examples. Thus *P.Hib.* 1.27 is an astronomical parapegma, a list of annually recurring phenomena including risings and settings of stars and constellations arranged in chronological order within a generic year, and this is a format that has abundant parallels in lapidary inscriptions and in texts preserved by the medieval manuscript tradition, though as it happens, we have no other instances on papyrus.[63] Again, P.Berlin inv. 13146+13147 and *P.Oxy. astr.* 4137 are eclipse canons, lists of predictions of consecutive eclipses covering some span of years. For the most part, however, the non-tabular texts represent a wide variety of genres of astronomical writing and can only be grouped loosely by subgenres such as didactic handbooks, mathematical treatments of spherical astronomy, discussions of astronomical observations, or procedure texts relating to tables or computations. Only a minority are datable with any precision by con-

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[63] Lehoux, *Astronomy, Weather, and Calendars* (2007).

tents, though these happen to include several important Hellenistic papyri: *P.Hib.* 1.27 (ca. 300 BCE), *P.Ryl.* 4.589 (180 BCE), *P.Par.* 1 (before 164 BCE), and P.Berlin inv. 13146+13147 (ca. 70 BCE). Thus, in contrast to the tabular papyri, we have non-tabular texts ranging from the early Hellenistic Period right through to late antiquity, though the preponderance are from the Roman Period. The rise of the tabular formats is doubtless to be attributed to the massive surge in popularity of astrology around the end of the 1st c. BCE. Astrology was utterly reliant on the availability of astronomical data, especially the longitudes of the Sun, Moon, and planets and the configuration of the zodiac relative to the horizon at any given moment, but it had scarce use for other kinds of astronomical knowledge.

§5. A Culture of Computation

In the list of recurring tabular formats in the foregoing section, I have repeatedly characterized the tabulated data as computed. How do we know this? In certain kinds of tables, we can see right away that the data are the product of calculations, not observations, because they exhibit easily recognized mathematical patterns that are not present in the natural phenomena. For example, the lunar longitudes associated with dates 248 days apart in *P.Lund* 35a always differ by exactly the same amount, 27;43,24,56° (or 27° 43' 24'' 56''') in sexagesimal notation.[64] Observed positions could scarcely have had a precision more refined than minutes, and even if they had, they would not have increased by a constant, let alone a constant like this, precise to the *thirds* place.

On the other hand, the almanac formats (1), (2), and (3) do not show such obvious patterns in the data. In his first 1942 study of the Demotic sign-entry almanacs P.Berlin inv. 8279 and the Stobart Tablets, Neugebauer recognized that the recorded dates of planets' crossing from one zodiacal sign to another cannot all be observed, because in many cases the planet in question would have been too close in longitude to the Sun to be visible. But, he maintained that it would be "a premature conclusion to assume from this fact that all positions must have been calculated."[65] He took particular note of a tendency of these almanacs to give much less accurate dates when the planet in question was moving retrograde (westward) than when it was in direct (eastward) motion, which he was inclined to explain as resulting from a mixture of observed and calculated positions.

By 1969, when he reedited the two Demotic almanacs with Richard A. Parker, Neugebauer no longer believed that they contained any observational data:[66]

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[64] Neugebauer, "Zur Geschichte der Babylonischen Mathematik," *Quellen und Studien zur Geschichte der Mathematik B* 1/1 (1926), 68, n. 3 introduced the convenient practice of separating sexagesimal "digits" with commas in transliterations, but with a semicolon between the whole number and the fractional part. In the Greek and Demotic adaptations of the Babylonian sexagesimal notation, only the fractional part of a number is expressed in base 60, whereas the whole number part is expressed using the normal non-place-value decimal notation.

[65] Neugebauer, "Egyptian Planetary Texts," *TAPS* 32/2 (1942a), 240–2.

[66] Neugebauer and Parker, *Egyptian Astronomical Texts* 3/1 (1969), 236.

> Increased experience during the last decades with a vastly enlarged mass of ancient astronomical tables has nowhere provided support for such a hypothesis which, we think, can now be safely discarded.

The reasoning is by default: one apparently should assume that the data in almanacs were computed *unless* we find positive evidence of observations (and by implication, what Neugebauer had thought was such evidence in 1942 no longer counted with him).

In fact B. L. van der Waerden had by this time argued a stronger thesis, that the almanacs were *demonstrably* computed by what he called "Babylonian" methods, by which he meant methods based on arithmetical sequences, as opposed to tables such as Ptolemy's in which trigonometric functions represented theoretical models composed of circular motions in the heavens.[67] In his later presentations of these analyses, responding to a highly skeptical critique by Neugebauer,[68] van der Waerden restricted consideration to just the data for three of the five planets in the Stobart Tablets (Jupiter, Mars, and Venus) and to the data for Jupiter alone in P.Berlin inv. 8279, compellingly demonstrating that the dates of Jupiter's and Mars' sign entries were computed by algorithms closely resembling algorithms attested in Babylonian mathematical astronomy, and that the dates of Venus' sign entries were computed by an arithmetical algorithm not known to be Babylonian in origin but closely resembling one in a 6th c. CE Sanskrit astronomical treatise, the *Pañcasiddhāntikā* of Varāhamihira.[69] Neugebauer eventually, if somewhat grudgingly, accepted van der Waerden's demonstration with respect to Mars in the Stobart Tablets, [70] though his general assessment of the methods underlying the almanacs remained cautious:[71]

> Hence one may perhaps conjecture that in the early hellenistic period (say in the second century B.C.), when Babylonian astronomy became known to the Greeks in some detail, methods were developed in Alexandria that adapted Babylonian procedures to the requirements of the new hellenistic astrology. But our material does not suffice to uncover the details of such a process.

The key point, though, is that, despite the difficulties inherent in analyzing sign entries, van der Waerden had definitively ruled out an observational component in enough blocks of the data to make it highly implausible that observation figured at all in composing sign-entry almanacs, or indeed any format of almanac.

Dependence on arithmetical methods can be easier to detect in ephemerides because characteristic patterns of arithmetical sequences will be apparent in sufficiently extensive runs of longitudes computed at one-day intervals, especially if they are given to a precision of minutes

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67. van der Waerden, "Egyptian 'Eternal Tables'. I," *KNAW Proceedings* (1947a), 536–47; *idem*, "Egyptian 'Eternal Tables'. II," *KNAW Proceedings* (1947b), 782–6; and "Babylonische Methoden in ägyptische Planetentafeln," *Vierteljahrsschrift* 105 (1960), 97–144.

68. Neugebauer and Parker, *Egyptian Astronomical Texts* 3/1 (1969), 236–40.

69. van der Waerden, "Aegyptische Planetenrechnung," *Centaurus* 16/2 (1972), 65–91; *idem*, *Science Awakening 2. The Birth of Astronomy* (1974), 308–23.

70. Neugebauer, *A History of Ancient Mathematical Astronomy* 1 (1975), 456.

71. Neugebauer, *A History of Ancient Mathematical Astronomy* 2 (1975), 789–90.

of arc, as is commonly the case. The lunar longitudes in *P.Oxy. astr.* 4176 (111 CE), 4177a (245 CE), 4178 (261 CE), and 4179 (348 CE), and the longitudes of Mercury in *P.Oxy. astr.* 4181 (161 CE) exhibit such patterns.

Decades before van der Waerden began exploring the possibility of "Babylonian" methods behind the almanacs, J. K. Fotheringham had found that a recently published papyrus ephemeris, P.Mich. inv. 1454 (467 CE), was entirely computed using Ptolemy's *Handy Tables*.[72] This has turned out to be true also for the three other known fragments of 5th c. CE ephemerides: P.Vind. inv. 29370 (489 CE), P.Vind. inv. 29370b (471 CE), and *P.Oxy. astr.* 4180 (465 CE). Five-day almanacs—the known examples date from between 217 and 349 CE—were all computed using either the *Handy Tables* or (less probably) the tables of Ptolemy's *Almagest*, but with a systematic adjustment to the planets' longitudes that reflects the assumption of a different zero-point from Ptolemy's for counting longitudes.[73] This adjustment is now known as "Theon's formula," because the algorithm for calculating it is stated by Theon of Alexandria in his *Little Commentary on the Handy Tables*.[74] Lastly, we have—only from Oxyrhynchus, so far—several fragments of sign-entry almanacs dating between 218 and 304 CE that have four columns of data instead of the usual three, because they give the hour of day or night as well as the date when each planet crosses from zodiacal sign to another. All were computed using the *Handy Tables* or *Almagest* tables adjusted by Theon's formula.[75]

From the perspective of present-day astronomical knowledge, these four-column sign-entry almanacs offer an entirely fictitious precision, since no ancient planetary theory could predict when the planets cross the sign boundaries to an accuracy even approaching an hour. They attest, however, to the prestige that Ptolemy's tables had gained by the 3rd century, and also to the effort that the composers of almanacs, whoever they were, were prepared to expend. Dates of sign entry cannot be calculated directly. Using arithmetical methods, one typically first calculated for a planet a sequence of date-longitude pairs corresponding to repetitions of one of its characteristic phenomena such as first morning visibility, and then one bridged the intervals of motion between these dates using arithmetical sequences. To find the dates of sign entry, one would need to determine the days on which the arithmetical sequence reaches one of the values 0°, 30°, 60°… 330°, while either increasing or decreasing, and this is not particularly hard to do. Using Ptolemy's tables, one has to calculate the longitude for each date more or less independently—there are some short cuts for doing a series of dates at fixed intervals, but nothing so simple as an arithmetical sequence—so that finding the date and time when a planet's

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[72] Fotheringham, Review of Curtis and Robbins, *An Ephemeris of 467 A.D.*, *The Classical Review* 49/6 (1935), 242.

[73] *P.Oxy. astr.* 4205–13 and P.Heid. inv. 34, published in Neugebauer, "An Astronomical Almanac for the Year 348/9," *Det Kongelige Danske Videnskabernes Selskab* 36/4 (1956). The derivation of P.Heid. inv. 34 from Ptolemy's tables with the systematic adjustment was demonstrated by Burckhardt, "Zwei griechische Ephemeriden," *Osiris* 13 (1958), 79–92, who credits van der Waerden with the identification of the adjustment as Theon's formula. The *Handy Tables* and *Almagest* tables yield essentially identical longitudes (within a tolerance of one or two minutes of arc depending on how one carries out the arithmetic) for the Sun and planets, but lunar longitudes derived from the *Almagest* average about 17' greater than those from the *Handy Tables* because of a difference in the definition of Alexandria mean time between the two works. P.Heid. inv. 34 includes a lunar ephemeris as well as the planetary almanac (for the dating see Neugebauer, "Astronomical Papyri and Ostraca," *PAPS* 106/4 (1962a), 385) but the longitudes appear to be too carelessly computed to tell what tables were used.

[74] Jones, *Astronomical Papyri from Oxyrhynchus* 1 (1999a), 343.

[75] *P.Oxy. astr.* 4190–2 and 4194–6a.

longitude assumes a given value such as 150° (the boundary between Leo and Virgo) becomes a matter of repeated testing of dates as the longitude from the tables converges on the goal value, probably finishing with a linear interpolation to get the precise hour. My recomputations using a computer program designed to simulate calculations by the *Handy Tables* mostly resulted in times of sign entry identical to those in the papyri, occasionally off by one hour, seldom more than that.

In contrast to this great mass of demonstrably computed astronomical data in the papyri, we have only a tiny number of observations pertaining to specific dates or astronomical events. The four papyri in question deserve a closer look:

> P.Berlin inv 13146+13147 is a 1st c. BCE papyrus whose front bears a Demotic text listing lunar eclipse possibilities (i.e., dates of oppositions on which the Moon's latitude is small enough for a lunar eclipse to be possible) at intervals of six or five lunar months between 85 and 74 BCE. These are, by their nature, certainly predictions, and most of the descriptions of the actual eclipses occurring at some of the eclipse possibilities are also clearly predicted. However, Neugebauer noted that some of the eclipse descriptions incorporate information (directions of obscuration of the Moon's disk at the beginning and end of the eclipse, and planets present in the sky) that he believed would have had to be observed.[76] In fact these are also predictable circumstances, so the question of whether this papyrus really records observations deserves reconsideration.
>
> *P.Oxy. astr.* 4133 is a 2nd c. CE fragment from a Greek astronomical treatise discussing the motions of Jupiter, citing observations of the planet made by an unknown astronomer in 241 BCE (who was probably the same as the unnamed astronomer whose observation of Jupiter from the same year is quoted by Ptolemy, *Almagest* 11.3) and by the author (perhaps Menelaus of Alexandria) in 104/5 CE. The manner in which the reports are presented resembles Ptolemy's *Almagest*.
>
> P.Fouad 267A + *PSI* 17.1674 comprises two fragments from a 2nd or 3rd c. CE codex page preserving the end of an astrological text and substantial passages from a text concerning how to use certain tables to calculate the Sun's longitude for a given date as well as other data dependent on the solar longitude, with worked examples for a date in 130 CE.[77] The astronomical text, which may be a student's somewhat garbled notes from a lecture on the practical elements of astrology, refers to an observation by Hipparchus of the summer solstice in 158 BCE, though no use is made of it. This observation is not cited in Ptolemy's *Almagest*, but in 3.1 Ptolemy cites observations of the autumnal equinox in 159

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[76] Neugebauer, Parker, and Zauzich, "A Demotic Lunar Eclipse Text," *PAPS* 125/4 (1981), 324.

[77] Fournet and Tihon, *Conformément aux observations d'Hipparque* (2014); Jones, "Unruly Sun," *JHA* 47/1 (2016a), 76–99.

> and 158 BCE from Hipparchus' *On the Shifting of the Solstitial and Equinoctial Points*.
>
> *P.Ryl.* 1.27, which has already been mentioned above, is a 3rd c. CE procedure text with a regnal canon (ending with the accession of Gallus, 250 CE) and rules for calculating the dates and times of solstices and equinoxes by extrapolating from dates of solstices and equinoxes "that Ptolemy observed." These are the observations of the summer solstice, autumnal equinox, and vernal equinox that Ptolemy reports that he made in 139–40 CE in *Almagest* 3.1 and 3.4, together with a calculated date of the winter solstice in 139 which is not in the *Almagest* (the text does not distinguish this one from the other three).

Thus, the observations in the three Roman Period papyri are all derived from the "scientific" literature of Greek astronomy represented by Ptolemy and by the earlier astronomers, such as Hipparchus, on whose works Ptolemy drew. Only the Demotic eclipse text *might* preserve data from an observational program that was close to the people who wrote and used the papyri. Their astronomy was a "day job" that scarcely involved looking at the sky.

§6. Babylonian Methods and their Adaptations

Babylonian astronomy during the period from the fourth through the 1st c. BCE had two major components reflected in distinct bodies of cuneiform texts.[78] The non-tabular texts classified by Sachs and more recently edited by Sachs and Hermann Hunger were the products of an extensive program of observation on a night-by-night and day-by-day basis, linked to a methodology of predicting future occurrences of the same kinds of phenomena directly from past observation records using known recurrence periods and fairly simple arithmetical adjustments. The tables and procedure texts edited by Neugebauer in *Astronomical Cuneiform Texts* applied much more complex arithmetical algorithms to generate whole streams of predictions of phenomena in a spreadsheet format. The datum in each cell of a table, usually a number in sexagesimal (base 60) notation, was generated by a formula from the datum in the cell in the row immediately above or data in one or more cells in columns to the left or data in cells both above and to the left. Only the starting row had to be obtained from observations or from some calculation external to the spreadsheet. This is the component commonly referred to as Babylonian *mathematical* astronomy, and it is also often simply called *ACT* astronomy from the acronym of Neugebauer's edition. *ACT* astronomy, which broadly speaking corresponds functionally to the computational astronomy of the Roman Period papyri, is extensively attested in tablets from two Babylonian sites, Babylon and Uruk. The observation-and-recurrence-period

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[78] The latest securely dated Babylonian astronomical texts, *Almanacs from Babylon*, are from 31/32 through 74/75 CE. Hunger and de Jong, "Almanac W22340a from Uruk," *ZA* 104/2 (2014), 182–94, have dated an Almanac from Uruk, to 79/80 CE, but this is less secure; if correct, the tablet would be more than two centuries more recent than the otherwise latest datable astronomical tablets from Uruk. The latest datable tablet of mathematical (*ACT*) astronomy, from Babylon, contains eclipse predictions ranging from 14/13 BCE through 42/43 CE, but at least some of these may have been forecasts.

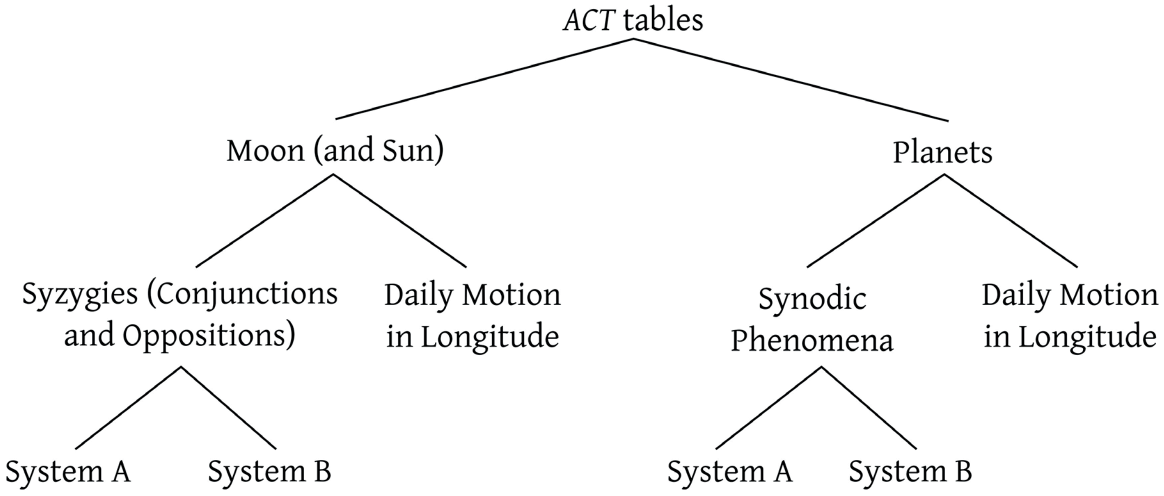

Figure 10.6. Taxonomy of tables in Babylonian *ACT* astronomy.

tradition, which is represented almost entirely by tablets from Babylon, has no counterpart in the papyri.

ACT was no closed and internally consistent system of prediction like Ptolemy's tables, but rather a repertoire of numerous algorithms that had in common the broad principle of modelling periodically varying spatial and temporal quantities by arithmetical sequences while varying considerably in the details of how this was done. Moreover, we often find several different algorithms in use more or less concurrently to predict the same phenomena. The great majority of the spreadsheets have a natural taxonomy (Fig. 10.6) according to the kind of heavenly body (Moon or a planet), whether the table deals with phenomena repeating at variable time intervals or daily motion, and whether key elements in the algorithms operate with so-called "step functions" (System A) or zigzag functions (System B). We have good representation among the surviving tablets for the lunar System A and System B for predicting circumstances of conjunctions and oppositions of the Moon with the Sun and lunar daily motion in longitude, and we have a pretty reliable knowledge of the algorithms and tabular formats that were in common use in Babylon and Uruk. For the tables of synodic phenomena of planets (events such as first and last visibilities and stations) there is a good number of surviving tablets, but also such a profusion of algorithms that it is difficult to be sure how close to complete our knowledge of the repertoire is. For example, we have attestations, in varying degrees of frequency (and sometimes only from procedure texts), of five System-A-type and two System-B-type algorithms for Jupiter's phenomena, while for Mercury and Venus we have distinct System A type models for each of the four recognized synodic phenomena (first and last visibility in the morning and evening). Our documentation for the treatment of daily motion of the planets is very poor: for Mercury and Jupiter we have one specimen each of a table of longitudes at one day intervals, as well as a few procedure texts.

Until the late 1980s, no astronomical table in a papyrus had been identified that was particularly like any of the *ACT* spreadsheets in content, method of calculation, and format. The papyri that looked most Babylonian in these respects were the templates, P.Carlsberg 32 for Mercury, *PSI* 15.1492 for Saturn, and *PSI* 15.1493 for the Moon, which employed arithmetical sequences to represent constant, accelerating, and decelerating motion in longitude in very much the same way as the *ACT* spreadsheets of planetary and lunar daily motion. A critical difference, however, was that the Babylonian tablets pertained to runs of specific dates, whereas the papyrus templates were dateless patterns designed to be applicable to repeating cycles of motion. Evidence that any of the *ACT* algorithms for calculating planetary synodic phenomena had been transmitted into the Greco-Egyptian tradition was indirect (as in van der Waerden's work on the sign-entry almanacs), or appeared to indicate that the algorithms had undergone extensive modification.[79] Of the System A and System B algorithms for lunar conjunctions and oppositions and the conditions of lunar visibility before and after these events, expressed in highly complex spreadsheets rising to as many as twenty data columns, there seemed to be no trace whatever. Concerning this absence, Neugebauer commented:[80]

> The theory of first and last visibility of the moon represents the most refined section of Babylonian mathematical astronomy. That no trace of such a theory has been found in Greek astronomy (in spite of the Greek adherence to lunar calendars) is a strong argument in favor of the opinion that not much more than some basic parameters were transmitted from Mesopotamia to the West.

That is why Neugebauer was so shocked by P.Colker. The papyrus preserved the right edge of one column of numerals, a second column that was mostly vacant but had indications that translate as "additive" or "subtractive" every six or so rows, and the right part of a column of numerals in sexagesimal notation. It was this third column that Neugebauer identified as the so-called Column G of a System B lunar spreadsheet, probably for a series of consecutive oppositions.[81] Column G, a linear zigzag function, is one of two components that, added together, represent the excess over 29 days of the time from the preceding opposition to the present one. Regarding P.Colker, Neugebauer remarked in 1988:[82]

> Since an isolated column (like our column G) is of no interest, our fragment not only demonstrates the existence, in a Greek version, of *one* component, but only makes sense as part of the whole numerical procedure.

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[79] In particular, Neugebauer, *A History of Ancient Mathematical Astronomy* 2 (1975), 946–8 had interpreted P.Heid. inv. 4144 + *P.Mich.* 3.151 as a table pertaining to a modified version of the Babylonian System A algorithm for Mars' first and last visibilities and first stations, an idea I further developed in Jones, "Babylonian and Greek Astronomy," *Centaurus* 33/2 (1990), 97–114. I am no longer convinced by this identification, though I do not have an alternative suggestion.

[80] Neugebauer, *A History of Ancient Mathematical Astronomy* 2 (1975), 829–30.

[81] In Neugebauer's notation in *Astronomical Cuneiform Texts* (1955), which has become standard, a "column" designated by a Roman or Greek letter refers to its astronomical meaning and method of computation, not to its physical position in any specific tablet fragment.

[82] Neugebauer, "A Babylonian Lunar Ephemeris," *A Scientific Humanist* (Fs Sachs) (1988), 301–2.

This inference has been borne out by subsequent discoveries. A fragment from Oxyrhynchus (not included in *Astronomical Papyri From Oxyrhynchus*, and still awaiting formal publication) proved to come from another System B spreadsheet, this time of conjunctions, and preserves Columns A and B, respectively the Moon's progress in longitude since the preceding conjunction and its running total, the Moon's longitude at conjunction.[83] Another, found in the Cairo Museum and reportedly also from Oxyrhynchus, contains System B Column H, the running total of which is the second component, Column J, that is added to Column G to obtain the length of the preceding lunation; from the evidence of this papyrus it was at last possible to identify the poorly preserved leftmost column of P.Colker as a run of Column J itself.[84] And finally, *PSI* 15.1491, which Neugebauer had tentatively identified as an introduction to planetary tables, turned out to be a summary description of a System B spreadsheet in which the leftmost columns were, in order, Columns A, B, H, J, and G.[85] Thus an entire functional component of the System B spreadsheets—the set of columns that leads to the prediction of dates and longitudes of conjunctions and oppositions—was in the repertoire of the astronomical papyri, essentially unmodified from the algorithms we find in the cuneiform tablets. As yet, however, we have no evidence in papyri for the continuation of these computations leading to predictions of eclipses or visibility phenomena. The lunar System A is also still unattested, though it is perhaps too soon to conclude that only System B was transmitted.[86]

ACT astronomy treated the problem of predicting the Moon's longitude on a given date separately from the predictions relating to conjunctions and oppositions. The commonly used system was simple, calculating the Moon's longitude at one-day intervals as the running total of a linear zigzag function that repeats its values exactly after 248 days. This is an approximation of 9 anomalistic months (the period of the principal component of the Moon's varying apparent speed), but not an especially accurate one, so that one would have had to recalibrate the calculations from external data every few years. The Babylonian zigzag function for lunar daily motion was described in full numerical detail already in the 1st c. BCE by Geminus, *Introduction to the Phenomena* chapter 18, and a template based on it has come to light (P.Fay. ined. Gc36 (2) = *P.Tebt. astr.* 7). However, the most widespread arithmetical method of calculating lunar longitudes—and also lunar latitudes, which were not part of the Babylonian system—was an epoch-table-and-template system (which I have called the Standard Lunar Scheme) that was clearly inspired by the Babylonian one but used different and generally more accurate parameters.[87] Our understanding of the Standard Lunar Scheme, based by now on numerous papyri

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[83] Jones, "Babylonian Lunar Theory," *Under One Sky* (2002), 168–9.

[84] Aish and Jones, "Another Greek Papyrus," *ZPE* 199 (2016), 131–6; Jones, "More Babylonian Lunar Theory," *ZPE* 199 (2016b), 137–43.

[85] Jones, "Babylonian Lunar Theory," *Under One Sky* (2002), 169–73.

[86] One numerical parameter of System A appears in *P.Oxy. astr.* 4139, in a theoretical context. Moreover, several parameters of System B, including a periodicity pertaining to the Moon's motion in latitude (a necessity for predicting eclipses), had long been known to have been incorporated in Hipparchus' researches on lunar theory, and the schemes for the seasonal variation in length of day and night of both System A and B had been found in adapted and geographically-extrapolated form in Greco-Roman sources; see Neugebauer, *A History of Ancient Mathematical Astronomy* 1 (1975), 308–10, and 2, 706–33. No one before 1988 took these to imply a wholesale, functional transplanting of the practice of generating System A or B spreadsheets, and indeed they are likely to reflect diverse channels of transmission.

[87] Jones, "Studies in the Astronomy of the Roman Period I," *Centaurus* 39/1 (1997b), 1–36, and Jones, *Astronomical Papyri*

in addition to the three (*P.Ryl.* 1.27, *P.Lund* 35a, and *PSI* 15.1493) that Neugebauer knew, is sufficiently complete that it is possible to reproduce its results, just as we can do for data derived from Ptolemy's tables.

The new papyri from Oxyrhynchus have had a comparable impact on our picture of the Greco-Egyptian reception of Babylonian planetary algorithms to that of P.Colker with respect to the lunar algorithms. Epoch tables similar in layout to *P.Lund* 35a but consisting of dates and longitudes of synodic phenomena of a planet, turned out to be fairly common: 15 were included in *Astronomical Papyri from Oxyrhynchus*, and four have been published since then from other collections, including P.Stras. inv. 1097, which Neugebauer knew of but did not identify correctly. They all appear to be computed by arithmetical methods, and most were certainly or probably based on *ACT* algorithms known from the cuneiform tablets. There are not yet enough examples of *ACT*-based planetary epoch tables to give us a reliable measure of the range of algorithms in use, but the attested ones (Systems A1 and A2 for Mercury, A for Mars, B for Jupiter, and B for Saturn) are all among the ones that are most frequently encountered in *ACT* spreadsheet tablets. P.Berlin inv. 16511 + *P.Oxy. astr.* 4160 is the sole instance we have so far of a planetary epoch table (for Jupiter) that employs a System-A-type algorithm not known from cuneiform sources.[88]

One of Neugebauer's objections to van der Waerden's hypothesis that the Demotic sign-entry almanacs were computed using "Babylonian methods" was that the Babylonian algorithm for finding the date of a planetary phenomenon presumed that one was operating with a lunar calendar. The time interval from one occurrence to the next of a phenomenon of a particular kind, expressed in thirtieths of a lunar month, is assumed to be equal to the interval in longitude between the two occurrences, expressed in degrees, plus a constant characteristic of the planet in question: "The transformation of the Babylonian lunar calendar to the Egyptian or Alexandrian norm would in itself constitute a major obstacle."[89] In the papyrus epoch tables we find the unexpectedly simple solution that the time interval, though now expressed in days, is still found by adding a constant to the longitudinal interval, but employing a different constant. Differences between dates predicted by the two methods turn out to be negligible. The fact that in or after the process of transmission the date algorithm was adjusted in a fundamental way instead of overlaying a conversion of calculated dates from a lunar calendar framework to the Egyptian calendar tells us that the person responsible for this adjustment had a *theoretical* understanding of how the original algorithm had been derived, not merely an operational knowledge of how to carry the algorithm out.[90]

We have seen that planetary templates such as we find in papyri are another innovation of the Greco-Egyptian tradition. It appears obvious that planetary templates were used together with planetary epoch tables to calculate a planet's longitude on a given date in a manner analo-

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from Oxyrhynchus 1 (1999a), 321–42.

[88] Britton and Jones, "A New Babylonian Planetary Model," *AHES* 54/4 (2000), 349–73.

[89] Neugebauer, *A History of Ancient Mathematical Astronomy* 2 (1975), 790.

[90] P.Berlin inv. 16511 + *P.Oxy. astr.* 4160, mentioned above for its unique System-A-style model for Jupiter, also employs yet another date algorithm. On the relationship of the three methods see Britton and Jones, "A New Babylonian Planetary Model," *AHES* 54/4 (2000), 355–7.

gous to the epoch tables and templates of the Standard Lunar Scheme, but the specifics of how this was done are not well understood. In the Standard Lunar Scheme, the epoch dates are always at intervals of 248 days (9 anomalistic months) or 303 days (11 anomalistic months), with the longitudinal intervals also proportionate to 9 and 11, so that a single template comprising 303 rows can be applied to extrapolate daily longitudes from every epoch in the table. For any planet except perhaps Venus, the computed epochs corresponding to any of the synodic phenomena have considerable variation in their intervals of time and longitude, and in the absence of relevant procedure texts it is difficult to see how standard patterns of daily motion would have been applied to bridge these intervals. We are far from being able to reproduce ancient computations of planetary longitudes, as we can for lunar longitudes computed by the Standard Lunar Scheme.

We can illustrate the complexities with the case of Saturn, a planet for which we have a comparatively good range of relevant papyrus tables. Two epoch tables are known for Saturn, *P.Oxy. astr.* 4161 (covering 23–92 CE) which tabulates the planet's first morning appearances, probably computed by System B, and PSI inv. 2 (paleographically 2nd century), which tabulates an unidentifiable synodic phenomenon, computed by System B. In System B, progress in longitude between successive phenomena is represented by a zigzag function with extreme values 11;14,2,30° and 14;4,42,30°, while the corresponding time intervals are a zigzag function with extreme values approximately 376 ⅔ and 379 ½ days. Even if we leave off all the fractions, intervals between successive phenomena can be 11° in 376, 377, or 378 days; 12° in 377; 378, or 379 days; 13° in 378, 379, or 380 days; 14° in 379, 380, or 381 days; or 15° in 380 or 381 days. If a System B epoch table was intended to be used in an epoch-table-and-template scheme, one can hardly suppose that a distinct template was provided for each possible interval.

We also have three templates for Saturn, *P.Oxy. astr.* 4166, *PSI* 15.1492, and *PSI* 17.1673 (paleographically 2nd–3rd century). *PSI* 15.1492 (paleographically 2nd century), covering a complete synodic cycle from first morning visibility to first morning visibility, bridges a longitudinal interval of 12;31,30° in 378 days; these are approximately the mean values. In *P.Oxy. astr.* 4166 (paleographically 3rd century) we have separate templates bridging a longitudinal interval of approximately 7;30° from second station to last evening visibility in 110 days, and a longitudinal interval of 3;20° from last evening visibility to first morning visibility in 30 days. *PSI* 17.1673 has a template bridging a longitudinal interval of approximately 9° from first morning visibility to first station in 118 days. The parameters for both *P.Oxy. astr.* 4166 and *PSI* 17.1673 derive from the *ACT* System A for Saturn, which assumes that the zodiac is divided into two fixed zones: a "slow" zone in which the intervals between first visibility and first station and between second station and last visibility are always approximately 7;30° in four lunar months and the interval between last and first visibility is always 3;20°, and a "fast" zone in which the intervals between first visibility and first station and between second station and last visibility are always approximately 9° in four lunar months.[91] The System A approach of dividing the zodiac into zones, within each of which a planet's synodic cycle is always the same, is clearly

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[91] Neugebauer, *A History of Ancient Mathematical Astronomy* 1 (1975), 439–40. The summary of parameters above slightly simplifies the not entirely consistent data for subdivisions of the synodic cycle in the *ACT* tablets.

more suitable for pairing with templates than System B's continually varying synodic intervals, and the existence of these System-A-based Saturn templates probably implies that there were System-A-based epoch tables for Saturn too. Even so, it remains unclear how one would have handled synodic cycles that involved the planet's crossing from one zone to the other.

§7. EGYPTIAN FROM GREEK OR GREEK FROM EGYPTIAN?

Neugebauer's explorations of astronomical papyri began with Egyptian-language texts and tables, and in his 1942 edition of the two Demotic sign-entry almanacs he engaged in a consideration of how these tables as well as the Demotic and Hieratic texts from the Carlsberg collection that he had previously studied were to be understood in historical relation to pre-Hellenistic Egyptian and Greek astronomy.[92] His arguments are worth revisiting, since they show how his thinking about the nature of the astronomy of the papyri was shaped by a combination of observations that remain valid and assumptions that would be difficult to sustain today. He begins his "Historical Commentary" with this remarkable declaration:

> The question usually raised about the astrological purpose of ancient astronomical texts seems to me to be without much interest. Our texts do not contain any reference to astrology and the fact that the positions of the planets in the zodiac are of astrological significance does not prove that these texts would not have been written without any interest in astrology. We can say even more: if these texts are of old-Egyptian origin then astrological purposes can certainly be excluded because no astrology existed in Egypt before the latest period of its history.

The last sentence eventually turns out to lack the force it seems to have at first reading, because within a few pages, after reviewing several passages concerning Egyptian science in Greek and Latin authors, Neugebauer will dismiss any substantial connection between the kind of mathematical-predictive-and-perhaps-observational astronomy represented by the almanacs and the "theoretical" Egyptian astronomy of the pharaonic period. But his skepticism of any presumption that the intended application of the almanacs was in astrology frames his approach to the main question he addresses, "whether our texts actually tell us something about Egyptian astronomy or whether they are merely Hellenistic science in Egyptian disguise," as one concerning which the primary evidence should come from the history of mathematical astronomy.

At the outset, he points to the use of the zodiacal signs as an "obvious" Greek element in the almanacs; in other words, although he was of course fully aware that the zodiac originated in Babylonia, he takes for granted that the immediate transmission must have been from Greek, not Babylonian, astronomy. His more developed argument tending to favor seeing them as "Hellenistic science in Egyptian disguise" rests on a speculative identification of the almanacs

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[92] Neugebauer, "Egyptian Planetary Texts," *TAPS* 32/2 (1942a), 235–43.

as the "Eternal Tables" (αἰώνιοι κανονοποιΐαι or κανόνες αἰώνιοι) mentioned in Ptolemy, *Almagest* 9.2 (ed. Heiberg 2.211), in the horoscope *P.Lond.* 1.130 (lines 12–13), and in Vettius Valens, *Anthologiae* 6.1 (ed. Pingree 232, a reference Neugebauer was not aware of at this stage). In making this equation, he failed to notice that the Eternal Tables, whatever they were, yielded numerical longitudes for the planets on given dates, which sign-entry almanacs cannot do; and the reasoning behind his dating of the Eternal Tables to before 200 BCE is at best tenuous.[93]

The conclusion of his 1942 discussion remained cautious:

> The problem of estimating the Greek or Egyptian influence is, as far as I can see, beyond our present limits of knowledge.

By 1975, however, Neugebauer had on the one hand conceded the pertinence of astrology to the question, and on the other offered a more definite verdict on the side of Greek origins:[94]

> Beginning with the Hellenistic period the rapid development of Greek astrology is also reflected in Egyptian documents… It is clear that these texts can no longer be considered as belonging to "Egyptian" astronomy although they were undoubtedly written by Egyptians. The methods, however, are purely Hellenistic and have no connection with the Egyptian past.

(I also remember a conversation with him in the early 1980s about the almanacs, in which he insisted that the methods of computation behind them were probably very crude.)

Several circumstances have provoked fresh thinking in recent decades about the relationship between the Greek and Demotic astronomical papyri and the practices and practitioners associated with them. First, we have become aware of, and are increasingly well informed about, the two Fayum sites Tebtunis and Medinet Madi (ancient Narmuthis) as centers of intense astrological activity based in Egyptian temples and functioning bilingually; and we also now have evidence of such activity in Demotic and Hieratic, again in a temple setting, at Athribis in Upper Egypt.[95] Secondly, the number of known Demotic astronomical papyri, especially tables, though still greatly outnumbered by those in Greek, has grown significantly, and we also now have a much wider range of table types represented by Demotic as well as by Greek exemplars. In addition to sign-entry almanacs—of which we now have a third specimen, P.IFAO Dmt. 31—the corpus of Demotic tables can claim a monthly almanac (P.Monts. Roca inv. 314), a lu-

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[93] On the Eternal Tables see Jones, "The Keskintos Astronomical Inscription," *SCIAMVS* 7 (2006), 35 and below in the present paper.

[94] Neugebauer, *A History of Ancient Mathematical Astronomy* 2 (1975), 565.

[95] An early discussion of the significance of Medinet Madi and Tebtunis for astrologically motivated astronomy is Jones, "The Place of Astronomy in Roman Egypt," *The Sciences in Greco-Roman Society* (1994b), 39–46. For Tebtunis see now Winkler, "On the Astrological Papyri," *Actes du IX^e^ congrès international des études démotiques* (2009), 361–75; for Medinet Madi, see Menchetti, "Un aperçu des textes astrologiques," *Actes du IXe congrès international des études démotiques* (2009), 223–39. The bibliographies for both sites with respect to newly identified and published texts have grown considerably in recent years. For new horoscopes from Athribis with a reedition of the horoscope O.Ashm. Dem. 633, previously published by Neugebauer and Parker, "Two Demotic Horoscopes," *JEA* 54 (1968), 231–5, but now identified as from Athribis, see Escolano-Poveda, "Astrologica athribitana," *JHA* 53/1 (2022), 49–87 and Winkler, "On the demotic-hieratic horoscopes," *JHA* 53/2 (2022), 328–77.

nar ephemeris (P.Carlsberg 638), three tables of computed syzygies (P.Vind. D 4876, O.Berlin P 30539, and E.E.S. Box 502, 14d), and a Standard Lunar Scheme epoch table (P.Fay. ined. 24/40 + P.Oslo inv. 1336 + PSI inv. D 146).[96] There is so far no instance of a table type attested in Demotic but not in Greek.

These considerations perhaps only tell us that Egyptian scholars in the temples were engaged in astrology in ways that overlapped with what the Greek-speaking astrologers of, say, Oxyrhynchus were doing, and that they employed at least a large subset of the same astronomical resources. This subset seems (on the face of present evidence) to consist of arithmetically-based algorithms and almanacs that were derived from them; and now that we have abundant proof that this arithmetical approach derived from an extensive transmission of methods from Babylonian mathematical astronomy, the priority question is no longer simply about which linguistic context the astronomy of the papyri first arose in, but about which one was the immediate point of contact with the Babylonian tradition.

The chronology of the evidence offers little help. Most of the relevant papyri date from no earlier than the beginning of the 1st c. CE, and already at that period we have astronomical papyri in both Demotic and Greek. The mere fact that a particular algorithm or variety of table or text is first attested in one or the other language does not provide a secure basis for deciding priority. For example, the earliest papyrus currently known that attests to the Standard Lunar Scheme is probably the Demotic P.Carlsberg 638, a lunar ephemeris covering dates in 13–14 CE. But the zigzag function for the Moon's daily progress in longitude on which the Standard Scheme is founded has an amplitude that appears to have been calculated by a distinctively Greek method of analyzing lunar eclipse observations (probably invented by Hipparchus), so its author must have been conversant with the Greek theoretical literature.[97] Again, the Demotic lunar eclipse canon P.Berlin inv 13146+13147 (ca. 70 BCE) is, by a considerable margin, the earliest papyrus we have belonging to the predictive style of astronomy, but the fact that it combines months and days according to the Egyptian calendar with Callippic Period year numbers—a Greek astronomical chronology tied to the Athenian calendar—proves some level of interaction with Greek sources and may even indicate that the Demotic text is an adaptation of a Greek-language original.[98]

But there are some unequivocal indications of direct Babylonian-Egyptian contact. An indirect but pertinent one is the iconography of certain of the zodiacal signs in Egyptian pictorial zodiacs from the Greco-Roman Period: Sagittarius is precisely the Babylonian Pabilsag, with two faces (human and lion), wings, and two tails (horse and scorpion); and Leo stands upon a snake-monster whose tail is pecked by a bird, just like the drawing on the Late Babylonian astrological tablet VAT 7847. These images, so far as I know, occur in no Greco-Roman zodiac, and they must have been transmitted through images, not verbal descriptions. Of course, the

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[96] Editions are forthcoming of P.IFAO Dmt. 31 and E.E.S. Box 502, 14d by J. F. Quack and A. Jones and of P.Fay. ined. 24/40 + P.Oslo inv. 1336 + PSI inv. D 146 by J. F. Quack, K. Ryholt, and A. Jones. For P.Carlsberg 638 see Hoffmann and Jones, "Astronomische und astrologische Kleinigkeiten V," *Enchoria* 30 (2006/7), 10–20; for O.Berlin P 30539 see Hoffmann and Jones, "Astronomische und astrologische Kleinigkeiten VI," *Honi soit qui mal y pense* (Fs Thissen) (2010), 233–6; and for P.Monts. Roca inv. 314 see Escolano-Poveda, "Astronomica Montserratensia I," *Enchoria* 36 (2018/9).

[97] Jones, "Studies in the Astronomy of the Roman Period I," *Centaurus* 39/1 (1997b), 10–11.

[98] Jones, "Calendrica I," *ZPE* 129 (2000a), 147–8.

pictorial representation of zodiacal signs is a different kind of knowledge from the technicalities of mathematical astronomy; but we now have Demotic texts, almost certainly from a temple context, that point to a comparable immediacy in the transmission of *ACT* algorithms.

The texts in question are on two ostraca, O.Ashm. Dem. 483 and 525+732+763, and they are procedure texts that relate to the computation of longitudes and dates of Mercury's first and last visibilities according to the Babylonian System A1 and A2 algorithms.[99] These algorithms were already attested in Greek epoch tables on papyri from Oxyrhynchus.[100] What is distinctive about the ostraca is that their texts can almost be characterized as theoretical. They describe explicitly the underlying conception of the zodiac as being divided for each of Mercury's synodic phenomena into zones that are in turn composed of "elementary steps" of equal length, whose boundaries constitute the entire set of longitudes at which the phenomenon will be predicted to occur over a centuries-long recurrence period. The concept of elementary steps was hypothesized independently by van der Waerden and Asger Aaboe as the theoretical basis of the Babylonian System A-type algorithms, but no explicit reference to them has ever been found in any cuneiform text (or in any Greek papyrus, for that matter).[101] It is astonishing that we have the first proof of them in Demotic ostraca. Their authors must have had a deep understanding of the workings of the *ACT* algorithms that argues for very close communication with the Babylonian scholars.

Obviously, we still have a lot to learn about the relationship between Egyptian and Greek in the practices of astronomy and astrology in Egypt. Rather than speaking of distinct communities of Egyptian-speaking and Greek-speaking users of astronomical papyri, it would be more accurate to recognize the existence of a temple-based bilingual community depending primarily on Demotic astrological handbooks but able to use tables in either Demotic or Greek, and of another community that only worked with Greek-language resources. Hence from the Tebtunis temple library we have both Greek and Demotic tables with no apparent distinction in the function of the two scripts, together with numerous astrological texts in Demotic; in one instance (P.Carlsberg 104) we even have a Greek almanac on the reverse of a Demotic astrological manual.[102] Among the Oxyrhynchus papyri, on the other hand, Egyptian-language texts are in general comparatively uncommon (though not as rare as reliance on the card-file inventory would suggest), and alongside hundreds of Greek astrological texts and astronomical tables, only a small handful of Demotic specimens of either genre have so far been identified.[103] If it turns out that the astronomical toolbox of *ACT*, and presumably

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[99] Ossendrijver and Winkler, "Chaldeans on the Nile," *"The Scaffolding of Our Thoughts"* (Fs Rochberg) (2018), 382–419.

[100] *P.Oxy. astr.* 4152–5 and 4156a; PSI inv. 1 (Jones, "Dai papiri della Società Italiana," *Istituto papirologico G. Vitelli, Comunicazioni* 7 (2007), 1–8).

[101] van der Waerden, "Babylonische Planetenrechnung," *Vierteljahrsschrift* 102/2 (1957), 187; Aaboe, "On Period Relations in Babylonian Astronomy," *Centaurus* 10/4 (1964), 1–10; Ossendrijver and Winkler, "Chaldeans on the Nile," *"The Scaffolding of Our Thoughts"* (Fs Rochberg) (2018), 402–3.

[102] We have a small number of Greek astrological texts from Tebtunis as well: *P.Tebt.* 1.276, 1.277, and 2.676. For the identification of 2.676 as astrological see Flemming and Hanson, "PTebt II 676 revised," *Greek Medical Papyri II* (2009) 183–99, who also provide evidence (p.188) that 1.276 and 2.676 were found in the temple complex.

[103] Quack, "The Last Stand?," *Problems of Canonicity and Identity Formation* (2016), 108–9 and 115–6, where it is suggested on the basis of the published Greek papyri that the relative proportion of Demotic to Greek astrological texts at Oxyrhynchus is significantly higher than the proportion for astronomical tables; but in fact, the fraction of the Greek astrological texts that have yet been edited is tiny.

also the many concepts in Greco-Roman and late Egyptian astrology that we can identify as originally Babylonian, passed in the first instance into an Egyptian-speaking environment, there remains to be explored how this knowledge diffused into milieus where Egyptian was not spoken or read, in Egypt and beyond.

§8. Ptolemy's and Other Kinematic Tables

The influence of Claudius Ptolemy's astronomical work was already noticeable among the astronomical papyri known to Neugebauer. As noted above, Ptolemy's name appears in *P.Ryl.* 1.27, both as an obviously spurious attribution of the text, ὑπόμνημα Πτολεμαίου, between two columns of the *Iliad* Book 1 (*P.Ryl.* 1.43) that occupies the front of the roll and associated with dates of two equinoxes and a solstice extracted (though the text does not say so outright) from Ptolemy's *Almagest*. Further, the astronomical data in the ephemeris P.Mich. inv. 1454 and the five-day almanac P.Heid. inv. 34 had been shown to be computed using Ptolemy's tables. *P.Ryl.* 3.522/523 (the separate numbers refer to the recto and verso of the same codex leaf) was known to be a fragment of a set of tables partly matching Ptolemy's *Handy Tables* (the table of noteworthy cities, with some divergences in textual detail from the versions in medieval manuscripts) and partly rearranging the *Handy Tables* table of oblique ascensions, while P.Lond. 1278 comprises fragments of codex leaves from one or two sets of tables—two hands are present—related in content to those of the *Almagest* and the *Handy Tables* though distinct from either. How has the present, greatly enlarged, body of astronomical papyri affected our understanding of Ptolemy's place in the astronomical and astrological practices they reflect?

Ptolemy wrote many works on astronomy—eight have come down to us through the medieval manuscript tradition, and we know of two or three others that did not—and one treatise on astrology. Here we are concerned chiefly with two: the *Mathematical Composition* (μαθηματικὴ σύνταξις), better known by its medieval nickname, the *Almagest*, and the *Handy Tables* (πρόχειροι κανονες). The *Almagest*, completed after 146/7 CE, is a systematic treatise in thirteen books on the deduction of quantified theoretical models for the motions of the heavenly bodies through a mathematical analysis of empirical facts and observations. Interspersed with the argumentative chapters are astronomical tables derived from the theoretical models. The tables are integral parts of the demonstrative structure of the treatise, some of them providing the means of computing data that will be used in later stages of the argument, others providing a verification that the models predict phenomena in agreement with their empirically known behavior. Taken together, the *Almagest* tables also amount to an almost complete set of the tables that an astrologer would require, though Ptolemy does not draw attention to that fact; and their distribution here and there throughout a work that would have taken up thirteen papyrus rolls would not have been particularly convenient for ready reference.

Sometime afterwards, Ptolemy produced the *Handy Tables*, a set of tables based on, and augmenting, the *Almagest* tables but incorporating various changes of format and a few updates of the underlying theory, clearly intended for astrology and other practical applications. We have Ptolemy's rather terse introduction to the *Handy Tables* as well as commentaries by Theon of Alexandria (second half of the 4th century), and from the information in those works it is possible to reconstruct the authentic *Handy Tables* themselves as a subset of larger assemblages of astronomical tables preserved in several Byzantine codices.

The parts of Ptolemy's tables that would have been most useful for astrologers include the tables (of the mean motion and anomaly types) for calculating the longitudes of the Sun, Moon, and planets for a given date, and the ascension tables by which one can convert times of day and night expressed in seasonal hours into uniform equinoctial hours as well as determining the ascendant, midheaven, and other astrologically significant points of the zodiac. For these quantities, the *Almagest* tables and the *Handy Tables* yield essentially indistinguishable results, except in the case of the Moon, for which a difference of about a half hour in the definition of Alexandria mean time assumed in the two sets of tables results in differences of about a quarter of a degree in the Moon's longitude computed for the same date and time.

Turning now to the papyri, we can start by taking note of five fragments or sets of fragments of manuscripts of the *Handy Tables* themselves: one in roll format (*P.Oxy. astr.* 4167) and four codices (*P.Oxy. astr*. 4168–71). To date, only one other papyrus has been identified as one of Ptolemy's works, namely *PL* II/33, a small fragment of Ptolemy's introduction to the *Handy Tables* in a bookhand paleographically dated to the late 2nd or early 3rd century—it is noteworthy that none of the *Almagest* (tables or text) has shown up on papyrus, given the prominence that work held in late-antiquity intellectual centers such as Alexandria. Four papyrus manuscripts are also known containing instruction manuals for the *Handy Tables* (the same genre as Theon of Alexandria's so-called *Little Commentary on the Handy Tables*) by unidentified authors other than Ptolemy; two of them contain worked examples for dates in 215 and 329 CE respectively.[104]

We have three or four manuscripts of tables that are closely related to Ptolemy's tables without closely matching either the *Almagest* or the *Handy Tables* in format: *P.Ryl.* 3.522–3, P.Lond. 1278 (possibly consisting of fragments from two manuscripts), and *P.Oxy. astr.* 4173. Of these, P.Lond. 1278 and *P.Oxy. astr.* 4173 contain tables whose contents are clearly derived from the *Almagest* rather than from the *Handy Tables*, but P.Lond. 1278 also has tables that, while not attributable to Ptolemy, exist in similar though not identical form in the Byzantine collections of tables mentioned above that incorporate the *Handy Tables*.

It has already been noted above that some almanacs and ephemerides were computed using Ptolemy's tables (or perhaps tables like the ones discussed in the foregoing paragraph that were based on Ptolemy). All five-day almanacs and all four-column sign-entry almanacs that are well enough preserved to check contain planetary longitudes that agree with longitudes computed from either the *Almagest* or the *Handy Tables*, with consistent application of Theon's Formula to convert tropical to sidereal longitudes. These are all from the 3rd or 4th century, covering date ranges between 217 and 349 CE. All ephemerides dating from the 5th century agree with the *Handy Tables*, without conversion of the longitudes; since the ephemerides have lunar as well as planetary longitudes, use of the *Almagest* can be ruled out. It would seem that Theon's rule, and the preference for using sidereal longitudes that motivated it, died out around 400 CE; but the

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[104] *P.Oxy. astr.* 4142–43. See also note 56 above.

really interesting enigma is how a conversion formula that Ptolemy himself certainly did not advocate came to be employed so widely within about half a century of Ptolemy's life.

The Ptolemy-related astronomical papyri, like those based on Babylonian methods, can be recognized and assessed individually and as part of a larger practice, despite still being comparatively few and often rather scrappy, because we can relate them to a much better-preserved corpus. If we did not have the ACT cuneiform texts, little of the arithmetically-based astronomy of the papyri would be understood even now, aside from perhaps the Standard Lunar Scheme. By contrast, we owe to the medieval manuscript tradition the substantially complete texts of Ptolemy's astronomical works with reference to which we can identify fragments of the *Handy Tables*, tables that reorganize material derived from the *Almagest* and *Handy Tables*, and almanacs that were computed using the tables. Ptolemy's works were the survivors of a larger and older Greek astronomical tradition that predicted the positions and phenomena of the Sun, Moon, and planets according to theoretical models based on combinations of circular motions. This non-Ptolemy kinematic tradition is also represented among the papyri, but little is yet known about it except for a small handful of individually interesting tables and texts, one relating to the Moon and Venus, four to the Sun:

> *P.Oxy. astr.* 4220: four fragments probably from three different sets of astronomical tables. Two of the fragments, from the same manuscript, belong to mean motion tables for the Moon. One of them tabulates the tropical longitude of the Moon's apogee, which implies that the underlying kinematic model differed from Ptolemy's not only in employing a sidereal frame of reference but also in having the Moon's first anomaly caused by a revolving eccenter rather than an epicycle. The other tabulates the elongation of the Moon from the Sun, which may indicate that the model, like Ptolemy's, involved a second anomaly dependent on that quantity. A third fragment comes from an anomaly table for Venus that assumes a slightly larger maximum anomaly than Ptolemy's, while the fourth is too damaged to identify.
>
> *P.Oxy. astr.* 4162: a template for the Sun, giving the Sun's longitude indexed by the number of the day counting from summer solstice. Exceptionally among all known templates, the longitudes were computed trigonometrically according to an eccentric (or equivalent epicyclic) model similar to Ptolemy's (cf. *Almagest* 3) except that the apogee was set at Gemini 13° 30', probably to be understood as sidereal, instead of Ptolemy's tropically fixed apogee at Gemini 5° 30'.[105]
>
> *P.Oxy. astr.* 4174a: mean motion tables for the Sun, in which the rates of mean motion are different for the Sun's motion in longitude, latitude, and anomaly. By contrast, Ptolemy's solar model assumes that the Sun has no motion in latitude, while the motions in longitude and anomaly are identical. The three periods underlying the papyrus are also attested in Theon of Smyrna's *Mathematics Useful for Reading Plato* (ed. Hiller, 172–3).[106]

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[105] Jones, "Studies in the Astronomy of the Roman Period II," *Centaurus* 39/3 (1997c), 211–7.

[106] Jones, "Studies in the Astronomy of the Roman Period IV," *Centaurus* 42/2 (2000b), 77–81.

PSI 15.1490: a text describing the construction of tables, probably a mean motion table and an anomaly table, and both probably pertaining to the Sun. Eccentric and epicyclic models are mentioned as being interchangeable.[107] As in *P.Oxy. astr.* 4174a, there were separate mean motions for longitude, latitude, and anomaly. The fragment is in the same hand, and may be from the same roll, as *P.Oxy. astr.* 4133 and 4134.

P.Fouad inv. 267A + *PSI* 17.1674: seemingly a student's rather incoherent notes from a lecture on how to calculate the Sun's longitude and certain derivative astronomical data for a horoscope, with worked examples for a nativity date in 130 CE.[108] The solar mean motion tables that were employed are substantially reconstructible. Three mean motions were tabulated, apparently not referring in the first instance to distinct elements of motion such as longitude, latitude, and anomaly, but reflecting different longitudinal frames of reference, e.g., sidereal, tropical, and a third according to which the mean year is exactly 365 ¼ days. The epoch date of the tables was 37,500 Egyptian years before the year 159/8 BCE, whose significance according to the text is that Hipparchus observed the date of the summer solstice in that year. The rates of mean motion have been adjusted in such a way that 37,500 Egyptian years contains exactly a whole number plus either ⅓ or ⅔ of each kind of solar year.

A previous section of this paper has referred to the allusions in Ptolemy's *Almagest* and other ancient sources to "Eternal Tables," which Neugebauer sought to identify with sign-entry almanacs. After initially accepting this supposition, van der Waerden later suggested that the "Eternal Tables" were tables similar to the methods of later Indian astronomy, in which extremely long temporal periods were made to contain integer numbers of multiple periodicities associated with heavenly bodies; agreeing with this hypothesis, Toomer further suggested that a better rendering of αἰώνιοι κανόνες would be "Aeon Tables."[109] The mean motion tables to which the present papyrus refers come close to meeting this description.

The part of the text dealing with solar anomaly and the calculation of the Sun's true longitude on the given date is lost, and the results seem to be contradictory, implying simultaneous assumption that the Sun's apogee has a sidereally and a tropically fixed longitude. This may reflect a misunderstanding on the part of the lecturer. Subsequent calculations concerning the lengths of seasonal hours and the Sun's declination made use of tables that were mathematically similar to, but formatted differently from, Ptolemy's tables for ascensions and declinations.

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[107] Jones, "Studies in the Astronomy of the Roman Period IV," *Centaurus* 42/2 (2000b), 81–87.

[108] Fournet and Tihon, *Conformément aux observations d'Hipparque* (2014); Jones, "Unruly Sun," *JHA* 47/1 (2016a), 76–99.

[109] van der Waerden, "Egyptian 'Eternal Tables.' I," *KNAW Proceedings* (1947a), 536–47, and "Egyptian 'Eternal Tables.' II," *KNAW Proceedings* (1947b), 782–8; van der Waerden, "Ewige Tafeln," *Arithmos-Arrhythmos* (Fs Fleckenstein) (1979), 285–93; Toomer, *Ptolemy's Almagest* (1984), 422, n. 12.

Evidently, we are far from having a critical mass of papyri for making more than isolated pockets of sense of the varieties of kinematic astronomy that competed with Ptolemy. This is the field where newly discovered texts have the greatest potential for advancing our knowledge and overturning expectations that we base on the sparse testimony of Ptolemy and other Greek and Latin authors.

The predictive astronomical tradition of the papyri spans something over five hundred years, from the first half of the 1st c. BCE (P.Berlin inv. 13146+13147) through the mid-5th c. CE (the several latest ephemerides). By the end of this interval, it had reached a convergence with the tradition perpetuated in the Byzantine manuscript tradition in that Ptolemy's tables had swept aside all rivals, whether arithmetical or kinematic. The easy explanation of this outcome is that *of course* Ptolemy won out, because his theories and tables were more accurate than the competition.

There is an element of truth in this. When one makes allowance for the systematic error in Ptolemy's tropical frame of reference for longitudes, which was zero around the mid-2nd c. BCE and increases by roughly a degree every three centuries, errors in predicted longitudes are at most on the order of a degree or less, except in the case of Venus around its interval of invisibility at inferior conjunction (when the errors can rise to about 5°) and Mercury (for which errors can exceed 8°).[110] Longitudes computed by arithmetical methods typically had much larger errors, through a combination of structural errors in the underlying models and inaccuracies in the observational data used to calibrate the computed sequences of phenomena.[111] But how would the users of tables, who as we have seen were no observers of the heavens, have come to be convinced that Ptolemy's tables gave the best results? And were Ptolemy's tables also the best among those of the kinematic variety?

We are unlikely to get an answer to the first of these questions from the papyri; the high reputation of Ptolemy's tables may have diffused among the astrologers from a more academic milieu in which the *Almagest*'s powerful demonstrative presentation of the theories, rather than any empirical testing, established Ptolemy's primacy. Some light on the second question, however, comes from a recently published papyrus horoscope, a demonstration that we should not write off this category of text as having little value for the history of astronomy.

P.Berlin inv. 9825 is an exceptionally well-preserved example of a Greek horoscope of the variety that I have called "deluxe" (or, if one prefers, "elaborate"), characterized by a higher level of both precision and detail in the presentation of the astronomical and astrological data associated with the nativity date.[112] In this case the horoscope, when complete, occupied at least a meter and a half of papyrus roll, of which more than a meter, comprising the data for the five planets (and a bit of the data for the Moon) and the astrologically significant points, is extant. The astrological part is of considerable interest in its own right, but for our purposes here, what

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[110] The most thorough treatment of the accuracy of Ptolemy's models (specifically for the planets) is Carman and Recio, "Ptolemaic Planetary Models," *AHES* 73/1 (2019), 39–124. See in particular the graphs of error in longitude against mean anomaly: p. 84, chart 30 (Mars); p. 87, chart 34 (Jupiter); p. 89, chart 36 (Saturn); p. 91, chart 38 (Venus, mislabeled "Mercury" in the caption); and p. 97, chart 40 (Mercury).

[111] We lack a broad systematic study of the quality of arithmetically computed longitudes in *ACT* and the papyri, but it suffices provisionally to compare the data in the better-preserved sign-entry almanacs with modern theory as in Neugebauer and Parker, *Egyptian Astronomical Texts* 3/1 (1969), pl. 70–73 and 75–78.

[112] Greenbaum and Jones, "P.Berl. 9825," *ISAW Papers* 12 (2017).

matters most is that it includes data from which the longitudes of the Sun, Moon, and planets can be restored (to a precision of minutes) where lost or verified where surviving. The horoscope also provides latitudes for the Moon and planets, and names for each one a zodiacal star that was nearby together with the difference in latitude between star and heavenly body. The nativity date can be reconstructed as November 19, 319 CE, just under an hour after midnight (likely representing the end of the 7th seasonal hour of night for the latitude of Syene).

What is immediately striking is that the longitudes were not computed from Ptolemy's tables but are collectively about as accurate relative to modern theory. The mean difference between the longitudes in the papyrus and modern theory is –25', whereas if one uses the *Handy Tables* for the same date, the mean difference relative to modern is –1° 49', so that if the longitudes in the horoscope are meant to be tropical, the frame of reference was significantly better than Ptolemy's. The planets' latitudes are also different from what one would calculate using either the *Almagest* tables or *Handy Tables* (which also differ from each other because Ptolemy modified his models for planetary motion in latitude), but the fixed stars agree exactly with the list of zodiacal stars in the *Handy Tables* both in nomenclature and latitude. Summing up, we can say that the astrologer who generated this horoscope used a set of kinematic tables that were different in content, not only in format, from Ptolemy's but of more or less equivalent accuracy, perhaps turning to the *Handy Tables* for the stellar data because the other tables lacked a star catalogue. It is fascinating to consider that, well into the 4th century, the *Handy Tables* were not the only high-quality astronomical tables in circulation.

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Appendix

This checklist is an expansion of the one I included as Appendix B in *Astronomical Papyri from Oxyrhynchus*, which in turn updated Neugebauer 1962a. It does not include *P.Oxy. astr.* 4133–4235, and its coverage of unpublished papyri is for the most part limited to those that either are in course of publication or have been referred to in print. It does, on the other hand, incorporate papyri devoted to Greek astronomical poetry, which were omitted from its predecessors. A single asterisk indicates a papyrus, or part of a papyrus, that was not in my previous checklist; a double asterisk indicates that the papyrus either is unpublished or has received only a description or a provisional or partial transcription; an obelus indicates a significant updating of the information in the previous checklist; an arrow indicates a cross-reference to another item in the checklist. Papyri that appeared in the previous inventories but that I do not consider to be astronomical are so indicated by brackets around the text identifier. The bibliographical notes are selective. I have provided Trismegistos (TM) numbers and the item numbers (N) in Neugebauer 1962a where they exist, and I have also indicated when there is a pertinent Neugebauer (ON) file in the University of Michigan Papyrology Collection.

*******P.Aberd.* 12. (TM 63745, N1) Roll. Greek. On the back of a Greek document, a text concerning northern constellations. 2nd/3rd c. CE (paleographical dating), purchased, from the Fayum? Discussion with textual remarks: Neugebauer 1962a, 384; Savio 2023. ON file with photos.

[†***P.Aberd.* 127 descr.] (TM 63746) Roll. Greek. Actually a fragment of an astrological text. 2nd/3rd c. CE (paleographical dating), from the Fayum? Discussion with textual remarks: Neugebauer and van Hoesen 1964, 58, who suggested that this is an astronomical text, not astrological as it was described (with transcription) in the original publication. However, line 4, which appears from the wider line-spacing above it to be the beginning of a new section, reads]ος ἐν Παρθένῳ ̣[, is clearly specifying the location in the zodiac of a heavenly body or astrologically significant point in a manner common in astrological texts and horoscopes, while θρόνος in line 2, which Neugebauer and van Hoesen call "rare in astrological context" and propose to identify as the throne of the constellation Cassiopeia, in fact frequently occurs in astrological prognostications of the "Sothis text" type (see *P.Oxy.* 31.2554 Fr. 1 ii 8 and Fr. 3 iii 4 and 8, and Hephaestio, *Apotelesmatica* 1.23, ed. Pingree 1973, 67 l. 3, 69 l. 19, and 71 l. 1). See now Savio 2023 who shows that the fragment joins *P.Gen.* 3.123. ON file with photo.

***P.Aberd.* 128 descr. (TM 63058, N2) Roll. Greek. Fragment of numerical table with sexagesimal fractions, of undetermined nature. 1st c. CE (paleographical dating), from the Fayum? Partial transcription in the original publication. Edition by A. Jones in preparation. ON file with photo.

Tab. Amst. inv. 1. (TM 65507) Wooden tablet, inscribed on one side. Greek. Sign-entry almanac. 26–24 BCE. Edition with photo: Neugebauer, Sijpesteijn, and Worp 1977. Discussion: Jones 1993 (dating); *idem* 2000a (identifying the year numbers as Callippic period years). ON file with photos.

*P.Ant. astr. (TM 754100) Codex. Greek. Ephemeris for 442 CE. Edition with photos: Jones and Pintaudi 2018.

P.Ant. 3.141. (TM 64332, cf. TM 63945 which refers to the same papyrus). Roll. Greek. Procedure text concerning computations of lunar longitudes. 3rd/4th c. CE (paleographical dating), from Antinoopolis. Previously identified by Neugebauer (in the commentary to the edition) as astrological. Discussion: Jones 1998a.

*O.Ashm. Dem. 483. Ostracon. Demotic. Procedure text on computations of Mercury's first evening visibilities by System A1. 1st c. CE. Edition with photos: Ossendrijver and Winkler 2018.

*O.Ashm. Dem. 525+732+763. Ostracon. Demotic. Procedure text on computations of Mercury's first morning visibilities by System A1 and last morning visibilities by System A2. 1st c. CE. Edition with photos: Ossendrijver and Winkler 2018.

*P.Berlin inv. 5865. Codex. Greek. Aratus, *Phaenomena*, with scholia. 4th c. CE (paleographical dating), from the Fayum? Edition with photos: Maass 1898, lxix–lxx, 556–8, and pls 1–2. Online description with photos: <https://berlpap.smb.museum/01625/>.

**P.Berlin inv. 6864 ined. Roll. Greek. Monthly almanac for Mars, 115/6 CE. Demotic text on back. Edition by A. Jones in preparation.

*P.Berlin inv. 7503 + 7804. (TM 59209). Roll. Greek. Aratus, *Phaenomena*. Edition: Schubart and von Wilamowitz-Moellendorff 1907, 47–54. Online description with photo: <https://berlpap.smb.museum/02244/>.

†P.Berlin inv. 8279 + *23547. (TM 55823, N3). Roll. Demotic. On the back of Greek accounts dated 42 CE, a sign-entry almanac covering 17 BCE–12 CE, from the Fayum. Edition of P.Berlin 8279 with photos: Neugebauer and Parker 1969, 228–32 and pls 66–73, superseding Spiegelberg 1902, 29–34 (with photo of cols iv–ix, pl. 99) and Neugebauer 1942a (with photos). Edition of inv. 23547 with photo: Hoffmann 1999. Discussion: van der Waerden 1947a, 1947b, 1960, and 1972. ON files (for inv. 8279) with photos.

**P.Berlin inv. 8344 ined. Codex. Greek. Sign-entry almanac. Edition by A. Jones in preparation.

**P.Berlin inv. 11491 ined. Roll. Greek Sign-entry almanac. Edition by A. Jones in preparation.

**P.Berlin inv. 11908 ined. Codex. Greek Sign-entry almanac. Edition by A. Jones in preparation.

P.Berlin inv. 13146 + 13147. (TM 45557 and 55822). Roll. Demotic. From Abusir el Melek. On front, a canon of eclipse predictions (85–74 BCE), apparently incorporating some observational data. On back, a text concerning dates of solstices and equinoxes in Egyptian calendar, 73–70 BCE. Edition: (back) Parker and Zauzich 1981; (front) Neugebauer, Parker, and Zauzich 1981. Discussion: Jones 2000a (identifying the year numbers in the eclipse canon as Callippic period years). ON file with photos.

→ P.Berlin inv. 14401. See P.Carlsberg 673.

→ P.Berlin inv. 14403b. See P.Carlsberg 228 + PSI inv. I 93 + P.Berlin inv. 14403b + P.Berlin 14467c + P.Berlin inv. 14474c + P.Berlin s.n.

→ P.Berlin inv. 14407b. See P.Carlsberg 496 + PSI inv. I 94 + P.Berlin inv. 14407b + P.Berlin 14441e + P.Berlin 29005 + P.British Museum 10973.

→ P.Berlin inv. 14439l. See P.Carlsberg 497 + PSI inv. I 95 + P.Berlin inv. 14439l + P.Berlin inv. 14481b.

→ P.Berlin inv. 14441e. See P.Carlsberg 496 + PSI inv. I 94 + P.Berlin inv. 14407b + P.Berlin 14441e + P.Berlin 29005 + P.British Museum 10973.

→ P.Berlin inv. 14467c. See P.Carlsberg 228 + PSI inv. I 93 + P.Berlin inv. 14403b + P.Berlin 14467c + P.Berlin inv. 14474c + P.Berlin s.n.

→ P.Berlin inv. 14474c. See P.Carlsberg228 + PSI inv. I 93 + P.Berlin inv. 14403b + P.Berlin 14467c + P.Berlin inv. 14474c + P.Berlin s.n.

→ P.Berlin inv. 14481b. See P.Carlsberg 497 + PSI inv. I 95 + P.Berlin inv. 14439l + P.Berlin inv. 14481b.

*P.Berlin inv. 16511. (TM 65958). Roll. Greek. On the back of a Greek document, a fragment of the same epoch table for Jupiter as *P.Oxy. astr.* 4160 (the edition there incorporates both fragments). Edition: Brashear and Jones 1999. Discussion: Britton and Jones 2000. Online description with photo: <https://berlpap.smb.museum/00021/>.

†P.Berlin inv. 21226. (TM 63067). Roll. Greek. On the back of a Greek document, a monthly almanac for Saturn covering 44–58 CE, from the Fayum. Edition (with incorrect interpretation as a monthly almanac for Jupiter): Brashear and Neugebauer 1973. Corrected interpretation: Jones 2009 (with photo). Photograph: Ioannidou 1996, pl. 58. ON file with photos. Online description with photo: <https://berlpap.smb.museum/record/?result=0&Alle=21226>.

P.Berlin inv. 21236. (TM 65513). Roll. Greek. Template for Mars, late 1st c. BCE (paleographical dating), from Abusir el Melek. Edition: Neugebauer and Brashear 1976, where it is described as an ephemeris for Mars, but the format (with an index column giving the day count since epoch every five lines) is that of a template. Photograph: Ioannidou 1996, pl. 61. ON file with photo. Online description with photo: <https://berlpap.smb.museum/record/?result=0&Alle=21236>.

P.Berlin inv. 21240. (TM 14722). Roll. Greek. Ephemeris. 3rd c. CE (paleographical dating), from Hermoupolis. Provisional transcription with photograph: Ioannidou 1996, 144 and pl. 62. Edition: Jones 1999c. Online description with photo: <https://berlpap.smb.museum/record/?result=0&Alle=21240>.

*P.Berlin inv. 21359. (TM 66063). Roll. Greek. Sign-entry almanac, from Oxyrhynchus. 3rd c. CE (paleographical dating). Edition: Jones 1999c (with photo). Online description with photo: <https://berlpap.smb.museum/record/?result=1&Alle=21359>.

→ P.Berlin inv. 23547. See P.Berlin inv. 8279 + 23547.

→ P.Berlin inv. 29005. See P.Carlsberg 496 + PSI inv. I 94 + P.Berlin inv. 14407b + P.Berlin 14441e + P.Berlin 29005 + P.British Museum 10973.

→ P.Berlin s.n. See P.Carlsberg 228 + PSI inv. I 93 + P.Berlin inv. 14403b + P.Berlin 14467c + P.Berlin inv. 14474c + P.Berlin s.n.

→ P.Berlin s.n. See P.Carlsberg 9 + P.Berlin s.n.

*O.Berlin P 30539. (TM 130029). Ostracon. Demotic. List of conjunctions of Sun and Moon, 184–5 CE. Edition with photo: Hoffmann and Jones 2010.

Bodl. MS Gr. Class. F 7 (P). (TM 63299, N4). Wooden tablet, inscribed on both sides. Greek Sign entry almanac, 99–102 CE. Edition with photos: Neugebauer 1972a, superseding Neugebauer 1957 (with photos). ON file.

O.Bodl. 2.2176. (TM 64205, N5). Ostracon. Greek. Text on 40-year cycle (?) of calendar dates (according to the reformed Egyptian calendar) of Sirius' rising in relation to new moons, with example dated 257 CE. Discussion: Neugebauer 1975, 946, and commentary to *P.Oxy.* 65.4473. ON file with photos.

O.Bodl. 2.2177. (TM 64204, N6). Ostracon. Greek. Part of a table or list of numbers (degrees and minutes?) followed by a date and longitude. 3rd c. CE (paleographical dating). Edition: Neugebauer 1974 (suggesting that the fragment lists longitudes of Jupiter on Choeac 15 of consecutive years). ON file with photos.

→ P.British Museum 10973. See P.Carlsberg 496 + PSI inv. I 94 + P.Berlin inv. 14407b + P.Berlin 14441e + P.Berlin 29005 + P.British Museum 10973.

[†P.Brooklyn Museum 16.619 (part) and 16.580.223 (parts)] (N7). Rolls. Greek. The fragments designated simply "P.Brooklyn Museum" in Neugebauer 1962a, which Neugebauer learned about in 1952 from Colin Roberts but were long presumed lost, can be identified from the photographs in Neugebauer's file. They appear to be fragments of two tabular horoscopes. ON file with drawing and photo.

*P.Cair. Mus. S. R. 3059 (part). (TM 65579). Roll. Greek. On the back is a table of computed syzygies based on the Babylonian System B, preserving Column H (differences of the solar component in the length of the preceding lunation). 1st c. CE (paleographical dating), perhaps part of the same roll as P.Colker. The front is mostly concealed by mounting but bears at least traces of writing. Edition with photo: Aish and Jones 2016. Discussion: Jones 2016b.

†P.Carlsberg 1. (TM 55984). Roll, with the text continuing from the front to the back. Hieratic and Demotic. Commentary on the so-called "Book of Nut," properly titled (according to von Lieven) "Fundamentals of the motion of the stars," comprising a cosmographical picture and texts known from the cenotaph of Seti I (1303–1290 BCE) and Ramses IV (1158–1152 BCE). 2nd c. CE (paleographical dating), from Tebtunis. Edition with photos: von Lieven 2007, 373–453 with pls 8–14, superseding Lange and Neugebauer 1940 and Neugebauer and Parker 1960, 37–80 and pls 36–42 and 44–54. ON file with photos.

†P.Carlsberg 1a + *PSI inv. I 92. (TM 55985). Roll. Hieratic and Demotic. Commentary on the "Book of Nut" (see P.Carlsberg 1), probably written by the same scribe as P.Carlsberg 1. From Tebtunis. Edition with photos: von Lieven 2007, 373–453 with pls 15–17, superseding Neugebauer and Parker 1960, 37 and 88–94, and pls 43–54.

†P.Carlsberg 9 (TM 55987, N8). Roll. Demotic. Schematic new moon dates. Later than 144 CE (by contents), from Soknopaiou Nesos. Edition with photo: Neugebauer and Parker 1969, 220–5 and pl. 65, superseding Neugebauer and Volten 1938. Three new fragments found in the Berlin collection have been transferred to the Carlsberg collection and are inventoried as part of P.Carlsberg 9: Zauzich 1974. (See also P.Heid. inv. Dem. 40 and 41.) Unpublished Demotic text on the back. Photograph of the augmented whole: Frandsen 1991, pl. 10. Discussion: Depuydt 1998; Quack 2017, 199, n. 55 (provenance). ON file (P.Carlsberg 9 only) with photo.

†P.Carlsberg 31 + **PSI inv. D 58. (TM 55988, N9). Roll. Demotic. Numerical table. 2nd c. CE (paleographical dating), from the Tebtunis temple library. Since the original publication, two more fragments have been found in the Carlsberg collection and one in the PSI collection; these are incorporated in the 2019 reedition. The table associates with a series of years numbered 1 through 100 (which is apparently the end of the table) an integer sawtooth function starting with 129 for Year 1 and decreasing by steps of 22 modulo 129 (i.e., whenever the value would become zero or negative, 129 is added). Aaboe 1972 identified the table as a 129-month cycle for determining schematic eclipse possibilities, but this interpretation requires assuming that the repeated indications of year numbers are errors for month numbers. If this is untenable, I would guess that the table is an astrological one (e.g., a scheme for lifespan) in which a pattern on the scale of years was constructed in imitation of an eclipse scheme on the scale of months. Edition with photo: Quack and Ryholt 2019, 355–9 and pl. 30, superseding Parker 1962 (with photo) and Neugebauer and Parker 1969, 241–3 and pl. 79A (not B as printed). Discussion: Aaboe 1972. ON file (P.Carlsberg 31 only) with photo.

P.Carlsberg 32. (TM 55989, N10). Roll. Demotic. Template for Mercury, morning station to last morning visibility. 2nd c. CE (paleographical dating), from Tebtunis? Edition with photo: Neugebauer and Parker 1969, 240–1 and pl. 79B (not A as printed), superseding Parker 1962 (with photo). Discussion: Hoffmann 2004/5. ON file with photo.

*P.Carlsberg 104. (TM 172209). Roll. Greek. Perpetual monthly almanac in a nonstandard format covering regnal years of Augustus through Nero (extrapolated beyond the end of his reign), second half of the 1st c. CE, on the back of a Demotic astrological text. Edition with photo: Jones and Perale 2013.

*P.Carlsberg 141. (TM 172211). Roll. Greek. Template for Venus. 1st c. CE, on the back of an unidentified Greek text. Edition with photo: Jones and Perale 2013.

*P.Carlsberg 228 + *PSI inv. I 93 + *P.Berlin inv. 14403b + *P.Berlin 14467c + *P.Berlin inv. 14474c + *P.Berlin s.n. (TM 102106). Roll. Hieratic. Commentary on the "Book of Nut" (see *P.Carlsberg* 1). From Tebtunis. Edition with photos: von Lieven 2007, 373–453 with pls 18–20.

*P.Carlsberg 239. (TM 172212). Roll. Greek. Mean motion table for the Moon. 2nd c. CE, on the back of a Demotic account. Edition with photo: Jones and Perale 2013.

*P.Carlsberg 496 + *PSI inv. I 94 + *P.Berlin inv. 14407b + *P.Berlin 14441e + *P.Berlin 29005 + *P.British Museum 10973. (TM 102107). Roll. Hieratic. Commentary on the "Book of Nut" (see P.Carlsberg 1). From Tebtunis. Edition with photos: von Lieven 2007, 373–453 with pls 21–22.

*P.Carlsberg 497 + *PSI inv. I 95 + *P.Berlin inv. 14439l + *P.Berlin inv. 14481b. (TM 102108). Roll. Hieratic. Commentary on the "Book of Nut" (see P.Carlsberg 1). From Tebtunis. Edition with photos: von Lieven 2007, 373–453 with pl. 23.

*P.Carlsberg 638. (TM 117866). Roll. Demotic. Lunar ephemeris, 13–14 CE. Edition with photo: Hoffmann and Jones 2006/7.

*P.Carlsberg 673 + *P.Berl. inv. 14401 + *PSI inv. D 94 + *PSI inv. D 19/5. (TM 91017). Roll. Greek. Monthly almanac, partly unfinished, covering regnal years 3 through 12 of Nero, 1st c. CE. On the back, fragments of the Demotic Book of Thoth. Edition with photos: Jones and Perale 2013.

P.Carlsberg 726. (TM 172213). Roll. Greek. Template for the Moon. 1st or 2nd c. CE, on the back of a Greek documentary text. Edition with photo: Jones and Perale 2013.

[†P.Carlsberg Committee number 10850.] Roll. Hieratic and Demotic. Now inventoried as part of P.Carlsberg 650, unpublished. A mythological text, included in the 1999 version of this checklist because of reported similarity to P.Carlsberg 1 and 1a, but it contains no certain reference to astral matters (information courtesy of Kim Ryholt). Notice: *P.Carlsberg* v. 1, 8.

**P.Col. inv. 525b. (TM 321192). Roll. Greek. From Aphroditopolis? On the back of a fragment of a Greek lease (second half of 1st c. CE), parts of what appear to be three columns of numerals, with the second being numbers in the 180s with one sexagesimal fractional place. If this is correct, the table must have been astronomical, though the meaning of the numbers is not clear. Edition: Lougovaya 2021.

†P.Colker. (TM 65579). Roll. Greek. On the back of a Greek document of unknown nature, a table of computed syzygies based on the Babylonian System B, including Columns J and G (solar and lunar components of the time interval since the preceding syzygy). First half of 1st c. CE (paleographical dating), perhaps part of the same roll as P.Cair. Mus. S. R. 3059 (part). Edition: Jones 1997a (for col. ii) and Jones 2016b (for col. i, with photo in Aish and Jones 2016, 132, Fig. 2), superseding Neugebauer 1988.

P.Dub. T.C.D. Pap. inv. F. 7. (TM 63233). Roll. Greek. Ephemeris, probably for April, 100 CE. Edition with photo: Hoogendijk 1982 (with an incorrect interpretation as a template for Venus). Discussion: Jones 1991 (developing this incorrect interpretation); Jones 1995 (with the present interpretation). ON file.

→E.E.S. 79/1(1)b is now P.Tebt. suppl. 1719. See *P.Tebt. astr.* 3.

→E.E.S. 79/82(1) is now P.Tebt. suppl. 1721 (= *P.Tebt. astr.* 1). See PSI inv. D 95.

→E.E.S. 79/82(2) is now P.Tebt. suppl. 1720. See *P.Tebt. astr*. 2.

**E.E.S. Box 502, 14d. Roll. Demotic. Table of computed syzygies, likely second half of 2nd c. CE, and likely from Oxyrhynchus. Edition by J. F. Quack and A. Jones in preparation.

→P.Fay. ined. s.n. (1). See *P.Tebt. astr.* 4.

→P.Fay. ined. s.n. (2). See *P.Tebt. astr*. 5.

→P.Fay. ined. Gc36. (1). See *P.Tebt. astr*. 6.

→P.Fay. ined. Gc36. (2). See *P.Tebt. astr*. 7.

**P.Fay. ined. 24/40 + P.Oslo inv. 1336 (TM 55990) + **PSI inv. D 146. Roll. Demotic. Epoch table for the Standard Lunar Scheme covering 152–65 CE, from Tebtunis. Edition with photo of P.Oslo inv. 1336 (as a table of unknown nature): Neugebauer and Parker 1969, 254–5 and pl.

79C. Edition of all fragments by J. F. Quack, K. Ryholt, and A. Jones in preparation. ON file (for P.Oslo inv. 1336) with photo.

P.Flor. 8. (TM 55982). Roll. Demotic. Concordance between decans and zodiacal signs. Roman Period (paleographical dating). Edition with photo: Neugebauer and Parker 1969, 252–4 and pl. 80C.

P.Flor. 44. (TM 55983). Roll. Demotic. Text concerning periods (?) involving Jupiter and moon. Perhaps astrological. Roman Period (paleographical dating). Edition with photo: Neugebauer and Parker 1969, 250–2 and pl. 80B.

*P.Fouad inv. 267A + **PSI* 17.1674. (TM 219739) Codex. Greek. Text on the use of tables to calculate the longitude of the Sun and related quantities for a given date, with an example for 130 CE, paleographically later 2nd or 3rd c. CE. Edition with photos (P.Fouad inv. 267A only): Fournet and Tihon 2014. Photos of *PSI* 17.1674 with the edition. Discussion: Jones 2016a.

**P.Gron. inv. 66. (TM 131624). Roll. Greek. On the front, parts of two rows from the bottom of a numerical table of unknown purpose. On the back, the other way up relative to the table, is a poem in praise of Alexandria (2nd c. CE, for which see Hendriks, Parsons, and Worp 1981, with photo of that side only). Edition by A. Jones in preparation. Photo online at <http://facsimile.ub.rug.nl/digital/collection/papyri/id/93/rec/25/>.

**P.Gron. inv. 125. Roll. Greek. Small fragment of an unidentified numerical table. Edition by A. Jones in preparation. Photo online at <http://facsimile.ub.rug.nl/digital/collection/papyri/id/152/rec/35/>.

**P.Hamburg* 2.121. Roll. Greek. Aratus, *Phaenomena.* Photo in the original publication, pl. 3.

**P.Hamburg inv. 717 ined. Roll. Greek. Sign-entry almanac, probably for 119/20 or 151/2 CE. Edition by A. Jones in preparation.

P.Harr. 1.60. (TM 63389, N11). Roll. Greek. Almanac-ephemeris for August, 140 CE. *P.Ryl.* 3.526 does not belong to the same document, as suggested in the original publication. New edition and discussion: Jones 1994a. ON file with photo.

P.Heid. inv. Dem. 40. Roll. Demotic. On the front, remains of five lines of text mentioning planets and Capricorn. On the back, slight remains of uncertain character. Edition with photos: Hoffmann 1997/8 (suggesting that the fragment belongs to P.Carlsberg 9).

P.Heid. inv. Dem. 41. Roll. Demotic. On the front, part of a regnal canon (including Augustus through Claudius). On the back, slight remains of uncertain character. Edition with photos: Hoffmann 1997/8 (suggesting that the fragment belongs to P.Carlsberg 9).

P.Heid. inv. G 34. (TM 64428, N12). Codex. Greek. Five-day almanac for 348/9 CE and syzygies and daily lunar longitudes for 345/6 CE, from a codex. Edition with photo: Neugebauer 1956. Discussion: Burckhardt 1958; Neugebauer 1975, 1056–7. ON file with photos.

P.Heid. inv. G 4144 + *P.Mich.* 3.151. (TM 64124, N13 and N22). Roll. Greek. Numerical table, interpreted by Jones 1990 as an auxiliary table for use with a modified version of the Babylonian System A scheme for Mars. 3rd c. CE (paleographical dating). Edition with photos: Neugebauer 1960. Discussion: Neugebauer 1975, 946–8; Jones 1990. Online description with photo of *P.Mich.* 3.151: <http://quod.lib.umich.edu/a/apis/x-3161/924.tif>. Online photo of P.Heid. inv. G 4144: <https://www.rzuser.uni-heidelberg.de/~gv0/Papyri/Verstreutes/4144_Neugebauer/4144_Neugebauer.html>. ON files (separately for each fragment) with photos.

P.Hib. 1.27. (TM 65691, N14). Roll, from mummy cartonnage. Greek. On the front, fragment *a* bears a text in epistolary form on Egyptian calendrics, and the remaining many fragments (in a different hand) bear a parapegma incorporating calculated lengths of day and night and Egyptian feasts, ca. 300–240 BCE (the early end of the date range based on the contents of the parapegma, the end on the paleography of the Greek texts on the back and dates assigned to other papyri from the same mummies), from el-Hibeh. The back of fragment *a* has Demotic writing, whereas other fragments have documents in Greek. Conceivably we are dealing with two distinct manuscripts. Photo of cols. iii (fragment *a*) and iv (fragment *b*) in the original publication, pl. 8. ON file with photos.

P.Iand. 5.84. (TM 63481, N15). Roll. Greek. Text on spherical astronomy. 2nd c. CE (paleographical dating). ON file with photo.

[P.Iand. inv. 654.] (TM 65180, N16). Sheet. Greek. Concordance of Julian and Alexandrian month names. 6th/7th c. CE (paleographical dating). Not explicitly astronomical. Edition: Gundel 1956. ON file with photo.

**P.IFAO Dmt. 31. Codex? Demotic. Sign-entry almanac, continuing from one side of the papyrus to the other. Edition by J. F. Quack and A. Jones in preparation.

O.Dem. Karnak ODK-NMB no. 2. (TM 91252). Ostracon. Demotic. Fragmentary text of astronomical or astrological contents, referring to zodiacal signs. Ptolemaic? (paleographical dating), from Karnak. Edition: Devauchelle 1987.

→*P.Köln* 4.186. See *P.Oxy.* 15.1807 + *P.Köln* 4.186.

P.Köln 10.400–1. (TM 68806 and 68805). Roll. Greek. On the front, a commentary on an astronomical poem. On the back, a commentary on Aratus, *Phaenomena*. 2nd to 3rd c. CE (paleographical dating). Photos in the original publication, pls 4 and 3. Online description with photos: <https://papyri.uni-koeln.de/stueck/tm68806>.

**P.Köln inv. 2353. (TM 643670). Roll. Greek. Small fragment of a numerical table, Perhaps a template, written across the fibers. 3rd c. CE (paleographical dating). Online description with Photo: <https://papyri.uni-koeln.de/stueck/tm643670>.

**P.Köln inv. 3239. (TM 643893). Roll. Greek. Calculations, perhaps of mean motions, on the front, 5th to 6th c. CE (paleographical dating). Traces of writing on the back. Online description with photo: <https://papyri.uni-koeln.de/stueck/tm643893>.

P.Laur. 4.144. (TM 64048). Codex. Greek. Sign-entry almanac, 68–71 CE (recto) and 92–95 CE (verso). Prior edition with photograph: Pintaudi and Neugebauer 1978. Revised edition of verso, with dating: Jones 1998a. Online description with photos: <http://www.psi-online.it/documents/plaur;4;144>.

P.Laur. 4.150. (TM 64867). Codex? Greek. Small fragment of a numerical table ("front," along fibers) and text (both sides), identified in the edition as "arithmetic-scholastic," but perhaps astronomical; cf. στηριγ[on back, line 5. 5th or 6th c. CE (paleographical dating). Online description with photos: <http://www.psi-online.it/documents/plaur;4;150>.

PL II/33 (Biblioteca Medicea Laurenziana). (TM 397898). Roll. Greek. A small fragment of Ptolemy's *Arrangement and computation of the Handy Tables*, in a bookhand dated paleographically to ca. 200 CE. Edition: Acerbi and Del Corso 2014.

**P.Lit. Lond.* 34 (= British Library Pap. 273 b) + P.Vind. inv. 29776. (TM 59218). Codex. Greek. Aratus, *Phaenomena*, with scholia. 4th c. CE (paleographical dating). Edition: Lenaerts 1968. Online description with photos of *P.Lit. Lond.* 34: <http://www.bl.uk/manuscripts/FullDisplay.aspx?ref=Papyrus_273&index=0>. Online description with photos of P.Vind. inv. 29776: <http://data.onb.ac.at/rep/10209891>.

P.Lit. Lond. 35 (= British Library Pap. 484 e). (TM 59210). Roll. Greek. Aratus, *Phaenomena*. 1st c. CE (paleographical dating).

P.Lond. 3.1278. (TM 63834, N17). Codex. Greek. Fragments from two (?) codices with tables related to the *Handy Tables* and *Almagest*. 2nd/3rd c. CE (paleographical dating). Edition: Neugebauer and Skeat 1958. Discussion: Defaux 2020, 85–86. ON file with photos.

P.Lund 5.35a. (TM 63530, N18). Roll. Greek. Epoch table for moon, 59–108 CE, compatible with rules in *P.Ryl.* 1.27. Edition with photo: Knudtzon and Neugebauer 1947. Discussion: Neugebauer 1949. ON file.

P.Lund 5.35b. (TM 63406, N19). Roll. Greek. Monthly almanac, 119/20 CE. Edition with photo: Knudtzon and Neugebauer 1947. Neugebauer suggested that this might be the same manuscript as *P.Tebt.* 2.274, which is in a similar hand. ON file with photo.

P.Mich. 3.149. (TM 63547, N20). Roll. Greek. An extensive astrological text, incorporating some astronomical material, e.g., dimensions of planetary epicycles and maximal latitudes, and oblique ascensions. 2nd c. CE (paleographical dating). Discussion: Aaboe 1963; Neugebauer 1972b; Neugebauer 1975, 805–8. Online description with photos: <https://quod.lib.umich.edu/a/apis?type=boolean;view=reslist;rgn1=apis_inv;select1=phrase;q1=P.Mich.inv.%25201>.

P.Mich. 3.150. (TM 64324, N21). Roll. Greek. Table of syzygies, similar in arrangement to the comparable table in P.Heid. inv. 34. 3rd/4th c. CE (paleographical dating). Discussion: Neugebauer 1942b, 251–2; Delporte 1947. Online description with photo: <http://quod.lib.umich.edu/a/apis/x-2120/3823r.tif>. ON file with photos.

→*P.Mich.* 3.151. See P.Heid. inv. 4144 + *P.Mich.* III 151.

P.Mich. inv. 29. (TM 63849). Roll. Greek. On the back of an astrological text, parts of two columns of text in a different hand (2nd/3rd c. CE). The contents of col. i appear to be astrological (at any rate not astronomical). Col. ii, however, might belong to a summary of the synodic cycle of an inner planet, broken up into specified numbers of days of visibility and invisibility. Edition and commentary: Ambühl, Markovska, and Milnor 1995. Online description with photos: <http://quod.lib.umich.edu/a/apis/x-1676/29v.tif> and <http://quod.lib.umich.edu/a/apis/x-1676/29r.tif>.

P.Mich. inv. 1454. (TM 64752, N23). Codex. Greek. Ephemeris for September and October, 467 CE. Edition: Curtis and Robbins 1935. Discussion: Fotheringham 1935; Sloley 1936; Burckhardt 1958. Online description with photos: <http://quod.lib.umich.edu/a/apis/x-1442/1454v.tif> and <http://quod.lib.umich.edu/a/apis/x-1442/1454r.tif>. ON file with photo.

**P.Mich. inv. 1466 ined. Roll. Greek. On the back of an unidentified Greek text, the other way up, a five-day almanac covering 302 CE. Edition by A. Jones in preparation. Online description with photos: <http://quod.lib.umich.edu/a/apis/x-6271/1466r.tif> and <http://quod.lib.umich.edu/a/apis/x-6272/1466v.tif>.

**P.Mich. inv. 5587e ined. Roll. Greek. Astronomical text. Edition by A. Jones in preparation. Online description with photo: <http://quod.lib.umich.edu/a/apis/x-14387/5587er.tif>.

**P.Mich. inv. 6635 ined. Roll. Greek. Astronomical text on parameters of lunar motion pertaining to the Standard Lunar Scheme. Edition by A. Jones and T. Gagos in preparation. Online description with photo: <http://quod.lib.umich.edu/a/apis/x-14701/6635r.tif>.

*P.Monac. Rehm. (TM 756240–43). Roll. Greek. Seven fragments from three to five distinct papyri of astronomical tables, copied by Albert Rehm in Munich in 1938–9 but no longer locatable. One of the tables is probably a template for Saturn, and another appears to have been a template as well though too little survives to identify the heavenly body to which it belonged. Edition: Jones 2018b.

*P.Monts. Roca inv. 314. Roll. Demotic. Monthly almanac, 71–73 CE. Edition: Escolano-Poveda 2018/9.

*P.Narm. 22.11.1998 (Cairo Museum). (TM 117885). Roll. Greek. Epoch table for Mars, acronychal risings computed by a variant of System A, probably 2nd c. CE. Edition: Jones 2008. Discussion: Stockhusen 2012.

[*O.Narm.* I 63–65.] (TM 29594–6). Ostraca. Greek. Ostraca from Medinet Madi (Narmuthis) consisting entirely, or almost entirely, of numerals. The editors suggest that these are notes for astronomical calculations; however, the numbers have no obvious astronomical meaning. Edition: Pintaudi and Sijpesteijn 1993, 81–83.

P.Nelson. (TM 63673). Roll. Greek. Monthly almanac, 101–3 CE. Edition: Nelson 1970. Discussion: Neugebauer 1971, Jones 1998a. ON file with photos.

P.Oslo 3.73. (TM 63280, N24). Roll. Greek. Text concerning instrumental measurement of the sun's diameter. 1st/2nd c. CE (paleographical dating). ON file with photo.

→P.Oslo inv. 1336. See P.Fay. ined. 24/40 + P.Oslo inv. 1336 + PSI inv. D 146.

*P.Oxford 79/105 (now in the Tebtunis Papyri collection at Berkeley). (TM 111739). Roll. Hieroglyphic. "Book of Nut" (see P.Carlsberg 1. From Tebtunis. Edition with photos: von Lieven 2007, 373–453 with pl. 7.

P.Oxy. 1.35 (= University of Pennsylvania Museum E 2749). (TM 20697, N25). Roll. Greek. On the back of a judicial edict, a regnal canon, with schematic lengths of reigns but no totals, Augustus to Decius (250 CE). From Oxyrhynchus. Online photo: <http://sceti.library.upenn.edu/pages/index.cfm?so_id=4057&pageposition=2&level=4>. ON file with photo.

P.Oxy. 2.303 descr. (= Bodleian MS Gr. Class. g 48 (P)). (TM 63185, N26). Roll. Greek. Text on lunar anomalistic motion. 1st c. CE (paleographical dating), from Oxyrhynchus. Edition: Neugebauer 1962a, 386–7. ON file with photo.

P.Oxy. 3.470 (= Dublin TCD F 8). (TM 63090, N27). Codex. Greek. Text on an astronomical or calendrical board (not a game), and on the construction of a water clock. 1st c. CE (paleographical dating), from Oxyrhynchus. Discussion: West 1989. ON file with photo.

[*P.Oxy.* 3.539 verso descr.] (TM 63864, N28). Roll. Greek. On the back of a fragment of the Iliad, unpublished, now at Columbia University (where it was for a while presumed missing). Neugebauer 1962a suspected from the brief published description that this small fragment belonged to *P.Ryl.* I 27. It does not, and the contents are a grammatical treatise or exercise.

**P.Oxy.* 15.1807 (now Edinburgh, University Library Ox. P. 14) + *P.Köln* 4.186. (TM 59212). Roll. Greek. Aratus, *Phaenomena*, with scholia. Photo both fragments in *P.Köln* 4, pl. 17. Online description with photo of *P.Köln* 4.186: <https://papyri.uni-koeln.de/stueck/tm59212>.

[*P.Oxy.* 15.1822 descr.] (TM 63594). Roll. Greek. On the back of an account, fragments of a hexameter poem alluding to comets and described in the original edition as "apparently relating to astronomy," but more probably astrological. 2nd c. CE (paleographical dating), from Oxyrhynchus. Editions: Perale 2020, 125–33; Lloyd-Jones and Parsons 1983, 412–4. Online description with photos (search for "1822"): <http://www.papyrology.ox.ac.uk/POxy/>.

[*P.Oxy.* 20.2258.] (TM 59424). Codex. Greek. The papyrus as a whole is a manuscript of poems of Callimachus with scholia, hence not *per se* astronomical. Quoted within a scholion to Callimachus' *Coma Berenices*, C fragment 1 back, are nine hexameter lines by a poet named Diophil–, comparing the form of Coma Berenices to that of the Pleiades. 6th to 7th c. CE (paleographical dating), from Oxyrhynchus. Editions: Perale 2020, 134–9; Lloyd-Jones and Parsons 1983, 179–81. Online description with photos (search for "2258"): <http://www.papyrology.ox.ac.uk/POxy/>.

***P.Oxy.* 30.2510. (TM 64485 for the early epic fragment on the front). Roll. Greek. On the back, not mentioned in the edition, is a table of unexplained purpose with regnal years of Augustus, Tiberius, Gaius, and Claudius. Discussion: Bravo 2001 (first published mention of the table).

**P.Oxy.* 30.2521. (TM 63626). Roll. Greek. Obscure hexameters, perhaps a quasi-mythological poem on the constellation Engonasin (Hercules), 2nd c. CE (paleographical dating), from Oxyrhynchus. Editions: Perale 2020, 140–7; Lloyd-Jones and Parsons 1983, 424–5. Online description with photos (search for "2521"): <http://www.papyrology.ox.ac.uk/POxy/>.

P.Oxy. 31.2551 (formerly *P.Oxy.* inv. 7 B/1959). (N29). Codex. Greek. Regnal canon, with schematic lengths of reigns but no totals, Cyrus to Philip (249 CE), and negligible remains of an astronomical (procedure?) text in a different hand, from a codex. From Oxyrhynchus. Edition: Sattler 1962, 39–50. Discussion: Parsons 1963. Online description with photos (search for "2551"): <http://www.papyrology.ox.ac.uk/POxy/>. ON file with photos ("P. Oxy. Inv. 7B 1959").

P.Oxy. 46.3299. (TM 64193) Codex. Greek. Sign-entry almanac, 217–25 CE, from Oxyrhynchus. Online description with photos (search for "3299"): <http://www.papyrology.ox.ac.uk/POxy/>. ON file with photo.

**P.Oxy.* 64.4423. (TM 59213). Roll. Greek. Aratus, *Phaenomena*, with scholia. 2nd to 3rd c. CE (paleographical dating). Online description with photos (search for "4423"): <http://www.papyrology.ox.ac.uk/POxy/>.

**P.Oxy.* 64.4424. (TM 59214). Roll. Greek. Aratus, *Phaenomena*, with scholia. 2nd to 3rd c. CE (paleographical dating). Photo in the original publication, pl. 11. Online description with photos (search for "4424"): <http://www.papyrology.ox.ac.uk/POxy/>.

**P.Oxy.* 64.4425. (TM 59211). Roll. Greek. Aratus, *Phaenomena*. 1st to 2nd c. CE (paleographical dating). Photos in the original publication, pls 12–13. Online description with photos (search for "4425"): <http://www.papyrology.ox.ac.uk/POxy/>.

**P.Oxy.* 64.4426. (TM 59215). Roll. Greek. Commentary on Aratus, *Phaenomena*. 2nd to 3rd c. CE (paleographical dating). Photo in the original publication, pl. 9. Online description with photos (search for "4426"): <http://www.papyrology.ox.ac.uk/POxy/>.

**P.Oxy.* 68.4648. (TM 68954). Roll or sheet. Greek. Prose text, a sort of literary history of star-sign lore, second half of the 3rd c. CE (paleographical dating). Photo in the original publication, pl. 6. Online description with photos (search for "4648"): <http://www.papyrology.ox.ac.uk/POxy/>.

**P.Oxy.* 83.5349. (TM 768445). Roll. Greek. Hexameters referring to the onset of autumn, the revolving of celestial circles, and the constellation Argo, 2nd c. CE (paleographical dating). Photo in the original publication, pl. 4. Edition: Perale 2020, 148–52.

**P.Oxy. 23 3B 1/O(1–4)c ined. Roll. Greek. Table of computed syzygies based on the Babylonian System B, including columns A and B. Discussion with provisional translation: Jones 2002.

P.Paris 1 (= P.Louvre N 2325 + N 2388). (TM 59770, N30). Roll. Greek. On the back, a set of acrostic verses, and on the front, a treatise on calendrical and elementary astronomical topics, early 2nd c. BCE. Surrounding the verses on the back are four official letters, two of them dated to 164 and 163 BCE. The original edition has a facsimile of both sides. Discussion and bibliography: Blass 1887 (with reedition); Neugebauer 1975, 686–9. Reedition by F. Schironi and A. Jones in preparation. ON file with photos.

[P.Paris Louvre inv. 7733.] (TM 65784). Roll. Greek. On the front, a text on optical phenomena, in part concerning the appearance of the celestial bodies near the horizon, but not properly an astronomical text. Epigram on the oyster on the back. 3rd/2nd c. BCE, from Memphis. Edition: Lasserre 1975, superseding Wessely 1891.

P.Petr. 3.134. (TM 65689, N31). Roll. Greek. Text mentioning decans and feasts in the Egyptian calendar. 3rd c. BCE (paleographical dating), from Gurob. ON file with photo.

*P.Petrie Mus. astr. Roll. Greek. Sign-entry almanac covering either 12 through 6 or 15 through 8 BCE. Edition with photo: Fanelli and Jones 2019.

→P.Pintaudi 12. See P.Yale 3609.

P.Ryl. 1.27. (TM 64100, N32). Roll. Greek. On the back of a manuscript of Iliad *Book* 1, a procedure text concerning the construction of epoch tables for the moon. Also rules for extrapolating solstices and equinoxes from Ptolemy's observations in 139/40 CE from *Almagest* III 4, and a regnal canon (schematic lengths of reigns and totals from Augustus' reign) from Commodus to Gallus (250 CE). Discussion: Neugebauer 1949; van der Waerden 1958; Jones 1983, 14–16; Jones 1997b (with corrections to edition). ON file with photo.

P.Ryl. 3.464. (TM 64101, N33). Roll. Greek. On the back of an official document, a small fragment of a procedure text (originally identified as 'apocryphal gospel'; cf. *P.Ryl.* v. 3, xvii). 3rd c. CE (paleographical dating). Online description with photo (search for "464"): <https://luna.manchester.ac.uk/luna/servlet/ManchesterDev~93~3>. ON file.

P.Ryl. 3.522/523. (TM 62679, N34). Codex. Greek. *Handy Tables*, oblique ascensions and table of noteworthy cities (codex). 3rd c. CE (paleographical dating), from the Fayum? Discussion: Defaux 2020. Online descriptions with photos (search for "522" and "523"): <https://luna.manchester.ac.uk/luna/servlet/ManchesterDev~93~3>. ON file with photo.

P.Ryl. 3.526. (N35). Roll. Greek. Fragments from a numerical table of unknown significance. 3rd c. CE (paleographical dating), from the Fayum? Cf. *P.Harr.* 1.60. ON file with photo.

P.Ryl. 4.589 (formerly P.Ryl. inv. 666). (N36). Roll. Greek. Text concerning dates of new moons. Early 2nd c. BCE, from Philadelphia? Prior edition and discussion: Turner and Neugebauer 1949. Online descriptions with photos (search for "589"): <https://luna.manchester.ac.uk/luna/servlet/ManchesterDev~93~3> ON file with photo ("P.Rylands Inv. 666").

[P.Schøyen inv. MS 1802/3.] (TM 220515). Roll. Greek. On the back of a register, four lines followed by traces, with numerals that seem to refer to day numbers, an hour number, and a mention of Ζυγῷ ("in Libra"). 1st c. CE (paleographical dating). Though published as a "fragment of a planetary table," this appears more likely to be astrological. Edition with photos: Pintaudi 2011/2.

PSI 13.1296. Parchment codex. Greek. Arithmetical scheme for length of daylight according to Alexandrian calendar months, written (7th/8th c. CE) over erased Coptic text. Online description with photos: <http://www.psi-online.it/documents/psi;13;1296>.

†*PSI* 15.1490 (formerly PSI inv. 515). (TM 65938). Roll. Greek. Procedure text concerning tables for the Sun. 1st/2nd c. CE (paleographical dating). Discussion: Manfredi 1966 (with

preliminary edition), Jones 2000b. Online description with photo: <http://www.psi-online.it/documents/psi;15;1490>. ON file with photo ("PSI Inv. 515").

†*PSI* 15.1491. (TM 63237, N37). Roll. Greek. Text describing the layout of a System B syzygy table. 2nd c. CE (paleographical dating). Discussion: Neugebauer 1962a, 388; Neugebauer 1975, 946; Jones 1984, 315–6 (all offering incorrect interpretations), Jones 2002. Online description with photo: <http://www.psi-online.it/documents/psi;15;1491>. ON file with photo.

PSI 15.1492. (TM 63448, N38). Roll. Greek. Template for Saturn. 2nd c. CE (paleographical dating), from Oxyrhynchus. Discussion: Neugebauer 1975, 790–1; Jones 1984. Online description with photo: <http://www.psi-online.it/documents/psi;15;1492>. ON file with photo.

PSI 15.1493. (TM 65583, N39). Roll. Greek. Standard Lunar Scheme template for the Moon. 2nd c. CE (paleographical dating). Discussion: Neugebauer 1975, 822–3; Jones 1983, 17–23. Online description with photo: <http://www.psi-online.it/documents/psi;15;1493>. ON file with photo.

***PSI* 17.1673. (TM 786064). Roll. Greek. Template for Saturn. Late 2nd or early 3rd c. CE (paleographical dating). On the back is a glossary to part of *Iliad* Book 1, published as *PSI* 17.1667.

→*PSI* 17.1674. (TM 786064) See P.Fouad inv. 267A.

*PSI inv. 1. (TM 111229). Roll. Greek. Epoch table for Mercury, last evening visibilities computed by System A2, 1st or 2nd c. CE. Edition with photo: Jones 2007.

*PSI inv. 2. (TM 111300). Roll. Greek. Epoch table for Saturn, computed by System B, probably 2nd c. CE. Edition with photo: Jones 2007.

→PSI inv. D 19/5. See P.Carlsberg 673.

→PSI inv. D 58. See P.Carlsberg 31 + PSI inv. D 58.

→PSI inv. 75 D. See PSI inv. D 95.

*PSI inv. D 92 + *P.Carlsberg 77. (TM 131508). Roll. Greek. On the back of a Demotic literary narrative, a table (probably a template) of daily longitudes of Mars, 1st or 2nd c. CE. Edition with photos: Jones and Perale 2011.

*PSI inv. D 93. (TM 131507). Roll. Greek. Sign-entry almanac covering 101/2 CE. Traces of Demotic on back. Edition with photo: Jones and Perale 2011.

→PSI inv. D 94. See P.Carlsberg 673.

†PSI inv. D 95 [formerly PSI inv. 75 D] + †P.Tebt. suppl. 1721 [formerly E.E.S. 79/82(1), = *P.Tebt. astr*. 1] + P.Yale 3609. (TM 63096). Roll. Greek. On the front, a monthly almanac covering from regnal year 9 of Claudius through regnal year 7 of Nero, 1st c. CE. On the back, fragments of the Demotic "Song of Horus of the Vineyard." Editions: (PSI inv. D 95) Manfredi and Neugebauer 1973 (with photo of part), (P.Tebt. suppl. 1721) Jones 1998b, Jones and Perale 2013 descr. Online description with image of P.Yale 3609: <https://findit.library.yale.edu/catalog/digcoll:2764841>. ON file with photos ("PSI Inv. 75D").

→PSI inv. D 146. See P.Fay. ined. 24/40 + P.Oslo inv. 1336 + PSI inv. D 146.

→PSI inv. I 92. See P.Carlsberg 1a + PSI inv. I 92.

→PSI inv. I 93. See P.Carlsberg 228 + PSI inv. I 93 + P.Berlin inv. 14403b + P.Berlin 14467c + P.Berlin inv. 14474c + P.Berlin s.n.

→PSI inv. I 94. See P.Carlsberg 496 + PSI inv. I 94 + P.Berlin inv. 14407b + P.Berlin 14441e + P.Berlin 29005 + P.British Museum 10973.

→PSI inv. I 95. See P.Carlsberg 497 + PSI inv. I 95 + P.Berlin inv. 14439l + P.Berlin inv. 14481b.

Stobart Tablets, Free Public Museum of Liverpool (Demotic). (TM 92644, N40). Painted wooden tablets. Demotic. Sign-entry almanac. 70–133 CE, from Thebes. Editions with photos: Neugebauer and Parker 1960–9, v. 3, 225–8, 232–40, and pls 74–78, superseding Stobart 1855 (facsimile), Brugsch 1856 (translation and discussion), and Neugebauer 1942 (with photos). Discussion: van der Waerden 1947a and 1947b; *idem* 1960; *idem* 1972. ON files.

*†P.Stras. inv. gr. 1097. (TM 63706, N41). Roll. Greek. Epoch table for Jupiter, last visibilities, probably by System B. 2nd c. CE (paleographical dating). Previous incorrect identification as a sign-entry almanac for Mars or Venus: Neugebauer 1962a; *idem* 1975, 788. Edition with photo: Jones 2018b. ON file with photos.

[P.Stras. 19 verso.] Roll. Demotic. Unpublished Demotic text on the back of a Hieratic fragment of the Book of the Temple, from Soknepaiou Nesos, described by Quack 2017, 202 as "barely legible remnants of what is probably a list of dates for the rotation of the phylae (temple staff working for one month at a time) by the moon calendar." If this is correct, the papyrus is not properly astronomical. See also Hoffmann and Jones 2010, 236.

P.Tebt. 2.274. (TM 63406, N42). Roll. Greek. Monthly almanac. 107–15 CE, from Tebtunis. Edition with photos: Neugebauer 1942a 241–2. Discussion: Neugebauer and Parker 1969, 233–4. Possibly from the same manuscript as *P.Lund* V 35b. Online description with photos: <https://dpg.lib.berkeley.edu/webdb/apis/apis2?invno=&apisid=297&sort=Author_Title&item=1>. ON file with photo.

P.Tebt. 2.449 descr. (TM 63407, N43). Roll. Greek. Daily longitudes of the moon during Mecheir of an unknown year. 2nd c. CE (paleographical dating), from Tebtunis. On the back, a Greek private letter. Edition: Carp 1975. Online description with photo: <https://dpg.lib.berkeley.edu/webdb/apis/apis2?invno=&apisid=296&sort=Author_Title&item=1>. ON file with photos.

→*P.Tebt. astr.* 1 (= P.Tebt. suppl. 1721, Grenfell and Hunt inv. T203, formerly E.E.S. 79/82(1), now in the Tebtunis Papyri collection at Berkeley). See PSI inv. D 95.

†*P.Tebt. astr.* 2 (= P.Tebt. suppl. 1720, Grenfell and Hunt inv. T202, formerly E.E.S. 79/82(2), now in the Tebtunis Papyri collection at Berkeley). (TM 63182). Roll. Greek. Monthly almanac for Mercury, in a nonstandard format. 2nd c. CE (paleographical dating), from Tebtunis. Edition: Jones 1998b.

†*P.Tebt. astr.* 3 (= P.Tebt. suppl. 1719, Grenfell and Hunt inv. T43, formerly E.E.S. 79/1(1)b, now in the Tebtunis Papyri collection at Berkeley). (TM 63181). Roll. Greek. Numerical table of unknown purpose in the format of a template. 2nd c. CE (paleographical dating), from Tebtunis. Edition: Jones 1998b.

P.Tebt. astr. 4 (= P.Fay. ined. s.n. (1)). (TM 67365). Roll. Greek. Sign-entry almanac, first half of the 2nd c. CE. Edition with photo: Jones 2001, 211–2.

P.Tebt. astr. 5 (= P.Fay. ined. s.n. (2)). (TM 67366). Roll. Greek. Sign-entry almanac. 229–33 CE. Edition with photo: Jones 2001, 213–5.

P.Tebt. astr. 6 (= P.Fay. ined. Gc36. (1)). (TM 67367). Roll. Greek. Monthly almanac for Mars. Probably 115/6 or 194/5 CE. Edition with photo: Jones 2001, 215–6.

P.Tebt. astr. 7 (= P.Fay. ined. Gc36. (2)). (TM 67368). Roll. Greek. On the back of a Greek register, a template for the Moon. 2nd c. CE. Edition with photo: Jones 2001, 216–20.

→P.Tebt. suppl. 1719. See *P.Tebt. astr.* 3.

→P.Tebt.. suppl. 1720. See *P.Tebt. astr.* 2.

→P.Tebt. suppl. 1721. See PSI inv. D 95.

P.Vind. inv. 3231. (TM 64250). Codex. Greek. Column headings from an ephemeris (not a horoscope). 3rd c. CE (paleographical dating, compatible with astronomical data). Edition: Neugebauer and Sijpesteijn 1980a. Online description with photos: <http://data.onb.ac.at/rep/10206E04>. ON file.

P.Vind. inv. 4876. (TM 55991). Roll. Demotic. Dates and times of syzygies. Roman Period (paleographical dating). On the back, a Greek document. Edition with photo: Neugebauer and Parker 1969, 243–50 and pl. 80A. Online description with photos: <http://data.onb.ac.at/rep/10203776>. ON files with photos.

P.Vind. inv. 26011 + 36041. Codex. Greek. Perpetual sign-entry almanac. Late antiquity (paleographical dating). Edition with photos: Neugebauer and Sijpesteijn 1980b. Discussion: Jones 1994c. Online description with photos: <http://data.onb.ac.at/rep/1020DA53>. ON file with photo.

P.Vind. inv. 29370. (TM 64799, N45a). Codex. Greek. Ephemeris. 489 CE. Edition with photo: Gerstinger and Neugebauer 1962. Discussion: Neugebauer 1975, 1057–8; Jones 1994c. Online description with photos: <http://data.onb.ac.at/rep/101FADBB>. ON file with photos.

P.Vind. inv. 29370b. (TM 64799, N45b). Codex. Greek. Ephemeris, 471 CE. Edition: Gerstinger and Neugebauer 1962. Discussion: Jones 1994c. Online description with photos: <http://data.onb.ac.at/rep/10220B3E>. ON file with photos.

→P.Vind. inv. 29776. See *P.Lit. Lond.* 34 + P.Vind. inv. 29776.

*P.Vind. inv. 40603. (TM 59216). Roll. Greek. Aratus, *Phaenomena.* 2nd to 3rd c. CE (paleographical dating). Edition with photo: Kramer 1982.

P.Vind., Institut für Österr. Geschichtsforschung. (TM 65768, N44). Roll. Greek. Text on weather prognostications, with some astronomical material including a shadow table. 3rd c. BCE (paleographical dating), from the Fayum. Editions: Wessely 1900, Neugebauer 1962b. ON file ("Vindob.-P. Wessely, S. B. Wien 142 (1900)") with photos.

→P.Yale (CtYBR) inv. 3609. See PSI inv. D 95.

*P.Yale (CtYBR) inv. 3775 = *P.Pintaudi* 12. (TM 144544). Roll. Greek. Sign-entry almanac, covering 223/4 CE and some preceding years. Edition with photo: Jones 2012. Online description with photos: <https://findit.library.yale.edu/catalog/digcoll:2765142>.

**P.Yale (CtYBR) inv. 3780 qua (fr. 5). Roll. Greek. On the back of an unidentified Greek text, the other way up, a tiny fragment of a table in red ruling. Col. i contains numerals, col. ii Egyptian month names. Online description with photos: <https://findit.library.yale.edu/catalog/digcoll:2765155>.

**P.Yale (CtYBR) inv. 3861 qua (fr. 18). Roll. Greek. On the back of an unidentified Greek text, the other way up, a tiny fragment of a table in red ruling. The one preserved column contains four rows of numerals decreasing in steps of 3 or 4 from 41 to 31. Online description with photos: <https://findit.library.yale.edu/catalog/digcoll:2765351>.

Addenda

Marina Escolano-Poveda is currently editing fragments of several Demotic tables that share the same hand as P.Monts. Roca inv. 314 and that appear to constitute the remains of a set: a syzygy table (P.Carlsberg 639v) and four fragments of monthly almanac (P.Monts. Roca inv. 1361v and 1362v, and P.Carlsberg 764r and 765r).

As Kim Ryholt and Benjamin Henry have informed me, a "scrap box" in the E.E.S. collection in Oxford designated A20 contains Demotic fragments demonstrably from Tebtunis, and in all probability its entire contents are from there. The sign-entry almanac *P.Oxy. astr*. 4186, which comes from A20, is thus from Tebtunis, not Oxyrhynchus. Several additional fragments of Demotic and Greek astronomical tables from A20 will be published as *P.Tebt. astr*. 8ff by Kim Ryholt, Marina Escolano-Poveda, and myself.

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