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ANCIENT ASTRONOMY AND CELESTIAL DIVINATION

Edited by N. M. Swerdlow

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A CLASSIFICATION OF ASTRONOMICAL TABLES
 ON PAPYRUS
 Alexander Jones

1 SUMMARY

After Mesopotamia, Egypt is proving the second most important source of archeologically recovered astronomical texts from antiquity. The principal modern collections of papyri from Greco-Roman Egypt are mostly the result of excavations and purchases from the decades surrounding the turn of the century.¹ But although the heyday of the recovery of papyri lagged only one or two decades behind that of the cuneiform tablets of Mesopotamia, it was only with O. Neugebauer's studies of astronomical papyri from the late 1940s to the late 1980s that their historical importance began to be appreciated.

Various causes, however, have long stood in the way of a systematic search for such texts. They were spread thinly among numerous, widely scattered collections. Inventories of unpublished papyri were scarce. And until a body of representative type-specimens had accumulated, even to know an astronomical fragment when one saw it often called for a degree of familiarity with astronomy and its history that a papyrologist could not be expected to possess. The still fundamental 1959 edition of horoscopes by Neugebauer and H. B. van Hoesen showed how much we might learn by studying even a category of documents that were meager in technical content but that could be hunted out in the world's collections with some claim to thoroughness because they were easy to recognize.² But astronomical papyri in the strict sense of the term came to light slowly and sporadically, and the sixty or so that Neugebauer knew gave the impression of a confusing variety of formats and contents of text with few instances of repetition.

In 1990, through the kindness of the Egypt Exploration Society, I obtained access to the trove of Greco-Roman papyri excavated between 1896 and 1906 by B. P. Grenfell and A. S. Hunt at the site of ancient Oxyrhynchus. Even after sixty-six published volumes containing more than 4,000 papyrus texts, the unpublished collection kept at the Ashmolean

Museum remains enormous, and a card inventory categorizes tens of thousands of the more substantial fragments by type or subject. It became swiftly apparent that this collection included unpublished fragments of astronomical texts and tables far outnumbering the entire hitherto published corpus. When tiny bits preserving only tabular ruling or traces of one or two numerals had been excluded, there remained more than a hundred new astronomical fragments (and about seventy new horoscopes), which I undertook to edit.³

Such a sudden increase in the number of documents available for study cannot help bringing with it a change in the way we study them. Where Neugebauer perforce treated each papyrus as an original problem of interpreting data of unknown meaning (and many of his articles are small classics of this genre), it is now often possible to identify the contents of a papyrus through its resemblance to known examples or its conformity to well established conventions. In fact, we are now entering the stage of scholarship, very stimulating for the modern student, where enough digested matter exists to be a real help in understanding new texts, but not so much that the new texts turn out to be mere repetitions of what has gone before.

Tables account for by far the majority of the known astronomical papyri, and among the insights to be gained from the new Oxyrhynchus fragments is the recognition of recurring, well-defined varieties and formats of table. In this paper I present a classification and nomenclature that I hope will be useful for the future identification, description, and analysis of astronomical tables. An exercise of this kind can never be definitive: the next hundred papyri to come to light may transform a present anomaly into a standard format. I have taken the opportunity to draw attention to instances where comparison with analogous texts has made it possible to extend or correct interpretations by Neugebauer and others (including myself) of previously published papyri; I have also slipped in some *obiter dicta* about the original applications of the various kinds of table and the underlying methods of computation.⁴

2 GENERAL DESCRIPTION OF THE DOCUMENTS

For convenience one often refers to the documents obtained from Egyptian sites collectively as papyri, but in fact other media are represented. The one that potentially most closely resembles papyrus in its uses, parchment, was rarely used for astronomical purposes. Ostraca were cheap but gave little space for writing, and so were most suitable for short

instructional texts, numerical jottings, and horoscopes. On the other hand, wooden tablets provided a handy and sturdy medium for tables that had to be consulted often, and we have examples of almanacs in this form.

Papyrus was manufactured in square or oblong sheets, and these could be used in several ways. Usually sheets would be joined to form a roll, which was by preference inscribed on the side that had its reed fibres running horizontally, although frequently the back side was later used for another text. The practice of binding sheets into a codex, which in general became common only in late antiquity, is often attested for astronomical tables—not surprisingly, given the awkwardness of a roll for ready reference. Finally, odd scraps of papyrus, sometimes cut from discarded documents, could hold shorter texts, tables, and especially horoscopes.

No known astronomical papyrus antedates the Macedonian conquest of Egypt, and among the few Hellenistic ones there are no tables or texts pertaining to tables.⁵ Our earliest astronomical table is probably *P. Oxy. 4175*, an ephemeris covering parts of the sixth and seventh regnal years of Augustus (24 B.C.), and astronomical papyri in general start appearing with some frequency in the first century of our era, reaching a peak in the second and third centuries, and thereafter the numbers taper off. The latest datable tables, again ephemerides, are from the second half of the fifth century. Great care must be taken in drawing inferences from the (present) lack of known tables from outside these limits, or the apparent flow and ebb between them, for at least in its broad outlines this pattern of distribution seems to parallel the chronological distribution of non-astronomical papyri. Most of the astronomical texts and tables (including all the ones from Oxyrhynchus) are written in Greek, but there is a significant minority in Demotic Egyptian.

Greco-Roman papyri have been discovered in numerous Egyptian sites between the Nile delta (where the water table is too high for their survival) and the southern frontier, with especially rich finds in the towns of the Fayyum and in Oxyrhynchus, the capital of the ancient Oxyrhynchite nome. So far as we can tell from the scattering of astronomical tables and horoscopes, astrology was to be found throughout this area; the very high number of astronomical texts from Oxyrhynchus is perhaps just a measure of the overwhelming bulk of papyri of all kinds that were retrieved there. Papyri in many other modern collections were purchased from dealers, and are of uncertain provenance. The circumstance that the great part of our Roman-era papyri came from the ancient rubbish heaps of the towns means that the specific sites of astronomical or astrological activity can seldom be identified. We do know from ostraca and papyri

found there that Egyptian temples in the Fayyum towns of Narmouthis (Medinet Madi) and Tebtynis were centers of astrological practice. But in general we are not dealing with archives from just one or two institutions with long-running scribal traditions, as was the case with the Babylonian astronomical tablets, so that it is not surprising to find less uniformity in the details of layout of the papyrus documents, written as they were during a span of more than five centuries.

The broadest categories of astronomical papyri are prose texts and tables. Very few of the texts are concerned with theoretical astronomy or observation, the majority being "procedure texts" directed to the production or use of the tables. The chief and almost unique goal of the astronomy represented in the Roman-era papyri was prediction: to find the zodiacal positions of the sun, moon, and planets and the disposition of the heavens at a given time in the past or future, and to determine the dates and circumstances of certain recurring phenomena such as eclipses and planetary appearances and disappearances. In turn these data were required for astrological prognostications and interpretations.⁶ We may further classify many of the tables under two general headings: "almanacs" that register dated positions of the heavenly bodies and other data at regular intervals,⁷ and "primary tables" that supplied the means by which the data in the almanacs as well as in the horoscopes were in the first instance computed. Both the almanacs and the primary tables occur in certain recurring varieties that are the subject of the ensuing classification. In addition, we have several isolated tables, some of them of unknown purpose, that do not as yet lend themselves to categorization.

With the exception of one or two fragments of theoretical treatises at one extreme and the personal horoscopes at the other, the astronomical papyri do not fit easily into the conventional dichotomy of papyrology into literary and documentary texts; hence they are usually assigned to a vague catch-all heading of "subliterary papyri," which embraces technical writings, but also magic and other ephemera, and in general those impersonal and unofficial texts that were valued in antiquity more for their content than for the precise means of expression. The handwriting (at least in the Greek papyri) is in accord with this ambivalent status: seldom a formal bookhand, still more rarely a true documentary cursive, but typically an intermediate "semiliterary" or "semidocumentary" hand comprising mostly disconnected letters but some characteristically documentary letter forms. Many of the numerical tables are carefully, even beautifully, executed, with neat rows and columns of entries in a red tabular framework. This kind of writing is often much more difficult to date on

paleographical grounds than verbal texts, so that it is fortunate that a high proportion of the astronomical tables can be dated reliably from their contents.

3 NOTATIONS IN THE PAPYRI

The most common information contained in the tables consists of dates and positions of heavenly bodies. This section describes various ways in which these are expressed.

3.1 Dates

The standard specification of a date is by year, month, and day. Years in the tables are almost always the regnal years of the current Roman emperor, counted such that the entire calendar year during which his accession occurred is his year 1. Rather than the elaborate official formulae of the documentary papyri, astronomical tables usually name the relevant emperor in a short form before or beside the first of a series of regnal years. Normally only the names of emperors who were still alive at the end of their accession year occur in astronomical datings. The schematic regnal canon underlying this reckoning, which is essentially the one preserved in medieval copies of Ptolemy's *Handy Tables*, diverged in other ways from the historical realities of political chronology; for example Commodus's regnal years were counted retroactively from the accession year of his father Marcus Aurelius, and likewise Caracalla's from that of Septimius Severus. The regular institution of co-emperors from the late third century on resulted in a great complication of civil dating formulae; the horoscopes from this time mostly eschew these conventions by reckoning years from the accession of Diocletian, but it is not yet clear whether the same practice was followed in tables.

Months are usually identified by name, or abbreviated name, but sometimes by an ordinal number counted from the first month of the year. The two calendars frequently encountered in the papyri, which we conventionally refer to as the "Egyptian" and "Alexandrian," used the same twelve months of thirty days supplemented by additional "epagomenal" days at the end of the year. In the Egyptian calendar year there were always five epagomenals. Near the beginning of Roman rule in Egypt, the Alexandrian calendar was adopted as the civil calendar as a reform of the Egyptian, adding a sixth epagomenal to every fourth year.⁸ Consequently an identical year number, month name, and day number in the two calendars referred to two dates, the interval between which grew

by one day every four years from the institution of the reform. This ambiguity would not have caused difficulty if the Alexandrian calendar had completely superseded the Egyptian, as indeed it did in most contexts. Unfortunately, however, astronomers persisted in employing the Egyptian calendar because its invariable 365-day year simplified computations involving time intervals. There did exist verbal formulae to specify the calendar used in a dating ("according to the ancients" = Egyptian, "according to the Greeks" = Alexandrian), but these were never used in the astronomical tables. We have to deduce which calendar is meant in a given table from the agreement of the corresponding astronomical data with recomputation by modern theory, from the regularity of time intervals between recorded dates (which can reveal the presence or absence of intercalations), or, failing that, from the known practice in other tables of the same type. Since the Alexandrian year always began on August 29 or 30, a given Alexandrian month and day will always correspond (within one day) to the same Julian calendar date, whereas the counterpart of a given Egyptian date falls progressively earlier in the Julian calendar.

Day numbers ought, of course, to range from 1 to 30. Occasionally (on analogy with longitudes?) a scribe has written day 0, instead of the 30th of the preceding month. A given day number applies, without qualification, to the interval from sunrise to sunset, and sometimes to the ensuing night. The more common designation of a night is by an expression of the time "night of the x th into the $x + 1$ th," which in some tables is represented simply by the numerals for the preceding and following day. Dates unaccompanied by an indication of time normally refer to some standard time of day, often the sunset ending the day in question (for computational purposes this is seldom distinguishable from 6 equinoctial hours past noon).

The usual "civil" expression for time of day is "hour x of day (or night)," where the hours are seasonal hours, that is, twelfths of the interval from sunrise to sunset or sunset to sunrise, counted from 1 to 12. The designation can in principle refer to any time during the hour in question, an ambiguity complicated by the occasional use of fractions. In certain tables, on the other hand, one encounters sexagesimal fractions following the day number (see the next subsection for the way these are written). These fractions can sometimes be meaningfully translated into times reckoned from the beginning of the day—whatever that may be. But in other cases, such as where the dates are of first or last visibilities of a planet, the time in question must be sunset or sunrise according the nature of the

phenomenon, and the fractions are merely part of the "bookkeeping" involved in computing the dates.

3.2 Positions

Most of the recorded positions are longitudes along the ecliptic, reckoned in degrees. (Except in the latest tables, these are always sidereal longitudes, although this is not important for our present purposes.) The longitude is regularly broken down into zodiacal sign, degrees (counted from 0 to 29 or from 1 to 30), and, optionally, one or more places of sexagesimal fractions. The zodiacal sign may be named in full or abbreviated to its first letters. Alternatively, it may be specified by its ordinal number (1 through 12) counted from Virgo = 1; the reason for this convention may be that the sun is in Virgo at the beginning of the Alexandrian year. The equivalences are as follows:

1 Virgo	5 Capricorn	9 Taurus
2 Libra	6 Aquarius	10 Gemini
3 Scorpio	7 Pisces	11 Cancer
4 Sagittarius	8 Aries	12 Leo

The sexagesimal notation is most frequently encountered in expressing longitudes, but occurs throughout Greek mathematical astronomy (and, with the significant exception of Ptolemy's *Harmonica*, nowhere else in Greek). It is used only for fractions, the integer part of a quantity being written in the normal way. The fractional places are separated from the integer part and from each other by spaces. Zero in a fractional place or as the whole number is written with a special symbol that usually is written $\overline{\circ}$.

Celestial latitudes seem to have been of very slight interest to the practitioners of the astronomy in the papyri. The argument of latitude of the moon, however, was apparently of enough astrological significance in its own right to call for frequent computation. It is always measured from the northern limit of the moon's orbit, sometimes in degrees, but more often in special units called steps (*bathmoi*) such that 1 step = 15° .

4 PRIMARY TABLES

4.1 Epoch Tables

The chief problem in predicting the day-to-day motion of the heavenly bodies is to take account of their cyclic variations in speed. One approach to this problem is to predict the successive occurrences of one or more

characteristic stages in the anomalistic cycle, and then to bridge the intervening intervals by interpolation or by applying a standard pattern of changing daily motion. We may name a table that lists epochs, that is, the dates and positions of one of the sun, moon, or planets at these characteristic moments, an "epoch table." Each epoch takes up one line of the table. Parallel columns of data may include the following:

(T). The date of the event. The Egyptian calendar is used in all the known epoch tables except one.

(ΔT). The interval of time (in days) between the preceding and current epoch.

(D). The number of accumulated intercalary days between equivalent dates in the Egyptian and Alexandrian calendars is sometimes tabulated in a column preceding the Egyptian calendar date, to allow ready conversion of dates to and from the Alexandrian calendar.

(B). The longitude of the relevant heavenly body.

(ΔB). The interval of longitude between the preceding and current epoch. This column is not attested in any known fragment, but probably was present in those epoch tables that had a column for ΔT .

The epoch dates so far attested in epoch tables for the sun and moon are, respectively, summer solstices and dates of minimum daily motion. For the planets, in all known cases except *P. Oxy.* 4157a (for which see below), the epochs are the so-called "Greek letter" phenomena of their synodic cycles. In this paper we will use Neugebauer's notations for these, which are the following:

Mercury and Venus

Γ First morning visibility

Φ Morning station

Σ Last morning visibility

Ξ First evening visibility

Ψ Evening station

Ω Last evening visibility

Mars, Jupiter, and Saturn

Γ First morning visibility

Φ First (morning) station

Θ Acronychal rising (opposition)

Ψ Second (evening) station

Ω Last evening visibility

The known examples of epoch tables are listed in table 1. It is worth remarking that before the discovery of the Oxyrhynchus fragments this format was represented only by a single specimen. All the epoch tables share this property, that the intervals in time and position from one tabulated epoch to the next are computed by arithmetical procedures of varying complexity. They are thus of considerable interest because they bring us closest to some of the methods and theoretical assumptions underlying the predictive astronomy of the papyri. The lunar tables are part of a skillfully crafted arithmetical system for computing lunar longitudes and arguments of latitude, which I call the "Standard Scheme."⁹ Most planetary tables were computed using the "ACT" schemes familiar from Babylonian astronomy, in most cases adapted only minimally to accommodate the use of a calendar working with real days instead of the idealized lunar calendar of the Babylonian tables.¹⁰

As an illustration of one of the possible arrangements of an epoch table, table 2 presents part of an epoch table for Mercury's first morning appearance (Γ), computed for the years Septimius Severus 19–22 (= A.D. 210/211–213/214) according to System A₁. The columns for D and T are taken from *P. Oxy.* 4153, with some restorations in the days and sexagesimal fractions. The other columns are entirely restored, and it is not certain that ΔT and ΔB were originally present. The months are represented in this translation by roman numerals in place of the abbreviated names in the papyrus. Table 3 shows a restoration of part of *P. Oxy.* 4161, a table of Saturn's Γ for Tiberius 9 through Gaius 2 (= A.D. 22/23–37/38) computed according to System B. The five columns contain, respectively, the regnal year, the ordinal number of the month, the day (with no fractions), the ordinal number of the zodiacal sign, and the integer number of degrees.

Remarks on Individual Texts

P. Oxy. 4148. Summer solstices. Only the dates are tabulated, because the longitude is assumed to be the same on all epochs. This table is discussed in Jones 1997b.

P. Lund 35a. Lunar epochs. Published with photograph in Knudtzon and Neugebauer 1947. The traces visible in columns i and x, not identified by the editors, are the remains of a column for D.

P. Oxy. 4149–4151. Lunar epochs. *P. Oxy.* 4149 is the only known epoch table to give dates in the Alexandrian calendar. *P. Oxy.* 4150 and 4151 both have part of the Standard Scheme template on the other side of the papyrus (in the case of 4151, this is published under a separate number, 4164). In

Table 1
Epoch tables

Text	Body	Years	Event	D	T	B	Other columns	Computation
P. Oxy. LXI 4148	Sun	161-237	Summer solstice	Yes	Yes	No		Constant year
P. Lund V 35a	Moon	58-108	Slowest motion	Yes	Yes	Yes		Standard Scheme
P. Oxy. LXI 4149	Moon	96-166	Slowest motion	No	Yes	Yes		Standard Scheme
P. Oxy. LXI 4150	Moon	187-198	Slowest motion	?	Yes	Yes		Standard Scheme
P. Oxy. LXI 4151	Moon	217-254	Slowest motion	Yes	Yes	Yes	Ω (vestigial)	Standard Scheme
P. Oxy. LXI 4152	Mercury	?	Ξ, Σ	?	?	Yes		System A ₁ , A ₂
P. Oxy. LXI 4153	Mercury	206-215	Γ	Yes	Yes	?		System A ₁
P. Oxy. LXI 4154	Mercury	?	Ω	?	Yes	?		System A ₂
P. Oxy. LXI 4155	Mercury	?	$\Omega, \Gamma, [\Sigma]$	?	?	Yes	$T_{\Gamma} - T_{\Omega},$ $T_{\Sigma} - T_{\Gamma}$	System A ₁ , A ₂
P. Oxy. LXI 4156a	Mercury	?	Ω	?	Yes	Yes		System A ₂
P. Oxy. LXI 4156b	Mercury	?	Γ	?	Yes?	Yes		?
P. Oxy. LXI 4157	Venus	?	?	?	Yes	?	ΔT	?
P. Oxy. LXI 4157a	Venus	106-121	Inferior conjunction	?	Yes	?	$\Delta T?$	?
P. Oxy. LXI 4158	Mars	271-325	$\Phi, \Theta?$	?	Yes	?	ΔT	System A
P. Oxy. LXI 4159	Mars	225-235	Γ	?	Yes	?		System A
P. Oxy. LXI 4159a	Mars	102-133	Ψ	?	Yes	Yes		System A variant?
P. Oxy. LXI 4160 + P. Berol. inv. 16511	Jupiter	57-80	$\Gamma?, \Phi$	No	Yes	Yes		System A' variant
P. Oxy. LXI 4160a	Jupiter	6-13	Γ	?	Yes	?	ΔT	System B
P. Oxy. LXI 4161	Saturn	23-92	Γ	No	Yes	Yes		System B

Table 2

Epoch table for Mercury: P. Oxy. 4153, lines 12-22, with restored columns

D	T				ΔT	B	ΔB
	19	I	23;2	119;53,20	☿ 16;13,20°	118;13,20°	
		V	8;51,10	105;49,10	♄ 0;22,30°	104;9,10°	
		IX	6;38,40	117;47,30	♁ 26;30°	116;7,30°	
59	20	I	8;42	127;3,20	☿ 1;53,20°	125;23,20°	
		IV	22;43,40	104;1,40	♄ 14;15°	102;21,40°	
		VIII	15;8,40	112;25	♁ 5°	110;45°	
		XII	29;22	134;13,20	♁ 27;33,20°	132;33,20°	
	21	IV	6;36,10	102;14,10	♄ 28;7,30°	100;34,10°	
		VII	24;16,10	107;40	♄ 14;7,30°	106°	
		XII	15;2	140;45,50	♁ 3;13,20°	139;5,50°	
	22	III	20;28,40	100;26,40	♄ 12°	98;46,40°	

some lines of 4151 the numerals purporting to be the lower order sexagesimal places of the epoch longitudes are in fact arguments of latitude (Ω) in steps, an intrusion suggesting an error in copying from an original that had a separate column for this quantity.

P. Oxy. 4152. "Greek letter" phenomena of Mercury. The epochs for Σ preserved on this fragment are actually mirror-reversed ink offsets on the back of the papyrus, transferred from a lost part of the same set of tables.

P. Oxy. 4155. "Greek letter" phenomena of Mercury. The remains of this table are in several small pieces. One group can be restored as a series of epochs of Ω , the other as epochs of Γ ; these seem to have been in separate parts of the manuscript rather than laid out in parallel columns. In each group, there are slight traces of an unidentified column of sexagesimals to the left, then a column containing whole numbers, and then a column giving the epoch longitudes. The middle column turns out to give the number of days from the tabulated epoch to the next phase of Mercury; that is, for Ω it contains the number of days from Ω to Γ , and for Γ it contains the days from Γ to Σ . On the basis of the latter, we are able to reconstruct a sequence of longitudes of Σ .

P. Oxy. 4157-4157a. Epochs for Venus. The tables for Venus that have come to light so far are frustratingly fragmentary, and little can yet be said about the basis of computation. The evidence for the Babylonian treatment of this planet is notoriously poor, and seems to offer no help with these tables. In 4157a, a preserved heading identifies the epochs as "morning conjunctions," that is, (as the dates reveal) inferior conjunctions. This is the unique

Table 3Epoch table for Saturn: *P. Oxy.* 4161, lines 1–16, with restorations

<i>T</i>	<i>B</i>			
9	8	12	7	11
10	8	26	7	24
11	9	10	8	8
12	9	24	8	21
13	10	8	9	5
14	10	23	9	19
15	11	7	10	3
16	11	21	10	17
17	12	5	11	1
18	12	19	11	14
19	13	2	11	27
21	1	11	12	10
22	1	24	12	23
Gaius				
1	2	4	1	5
2	2	20	1	17

exception to the rule that planetary epochs are observable “Greek-letter phenomena.” Conjunctions may have been preferred for Venus in order to disentangle this planet’s comparatively uniform pattern of longitudinal motion from the irregularities of its visibility phenomena.

P. Oxy. 4160 + *P. Berol. inv.* 16511. Γ and Φ of Jupiter. The longitudes and dates are computed by a previously unattested System A style scheme related to the Babylonian System A’ for Jupiter. The newly discovered Berlin fragment will be published in a forthcoming article by W. Brashear and A. Jones.

P. Oxy. 4161. Γ of Saturn. As noted above, the months and zodiacal signs in this table are represented by ordinal numbers. This is so far the only epoch table that uses this practice, which is common in almanacs.

4.2 Templates

“Templates” (cf. table 4) are tables that describe the progress of a heavenly body on the days following an epoch event. Such tables were evidently used in conjunction with epoch tables in order to compute the positions of the sun, moon, and planets on arbitrary dates. The majority of known templates count days continuously from one occurrence of an epoch event to the next occurrence of the same event (e.g., from Γ to Γ), but some planetary templates describe the planet’s progress only during part of its synodic cycle (e.g., from Ψ to Ω). Like the epoch tables, most templates are computed according to arithmetical procedures. Here, however, the dependence on Babylonian astronomy is less direct; for although the representations of lunar daily progress by a linear zigzag function (as in the Standard Scheme) and of planetary motion by linear and second-order arithmetical sequences are already attested in cuneiform texts, it is in the papyri that we first find such sequences tabulated as a standard pattern of increments in longitude, to be added to an arbitrary epoch position. It is also noteworthy that, whereas all the lunar templates that we have are essentially copies of the same table, the other templates show considerable variations in structure and parameters, even when two pertain to the same body.

The columns of a template may include:

- (T'). The number of days since epoch, increasing by steps of 1 day from 1, but generally recorded only at multiples of 5.
- (B'). The increase in longitude since epoch in degrees.
- (B). For the sun, the actual longitude is recorded instead of B' , because the longitude is assumed to be always the same at epoch.
- (ΔB). The increase in longitude since the preceding day.
- (Ω'). The moon’s increase in argument of latitude since epoch in steps.

Table 5 presents *P. Oxy.* 4166 as an illustration of a template; the whole of the first column for T' and parts of the others are restored. The planet in question is Saturn, with the leftmost three columns giving the end of the interval of motion from Ψ to Ω as a second-order sequence, and the remaining two giving the end of the shorter interval from Ω to Γ as a linear sequence. T' is not counted continuously from one interval to the next. Between Ψ and Ω , ΔB increases by constant $0;0,4^\circ$. If we extrapolate backward, we find that for day 0 (which was probably not actually written in the table), $\Delta B = 0;0,23,27,16^\circ$ and $B = 0^\circ$ exactly. From Ω to Γ , ΔB is a constant $0;6,40^\circ$ (not tabulated in the papyrus), and

Table 4
Templates

Text	Body	Epoch	Complete period?	T'	B'	ΔB	Other columns	Computation
P. Oxy. LXI 4162	Sun	Perigee	Yes	Yes	No	No	B	Trigonometric
P. Oxy. LXI 4163	Sun	Summer solstice	Yes	Yes	No	No	B	Linear sequences
PSI XV 1493	Moon	Slowest motion	Yes	Yes	Yes	No	Ω'	Standard Scheme
P. Oxy. LXI 4150	Moon	Slowest motion	Yes	Yes	Yes	?	Ω'	Standard Scheme
P. Oxy. LXI 4164	Moon	Slowest motion	Yes	Yes	Yes	Yes		Standard Scheme
P. Oxy. LXI 4164a	Moon	Slowest motion	Yes	Yes	Yes	Yes		Standard Scheme
P. Carlsberg 32 (demotic)	Mercury	Γ	?	Yes	Yes	Yes		2nd order sequence
P. Oxy. LXI 4217	Mercury	Γ	No	?	Yes	No		2nd order sequence
P. Oxy. LXI 4217a-c	Mercury	Ξ, Γ	No	?	Yes	No		2nd order sequence
P. Oxy. LXI 4165	Mars	Ψ	No	Yes	Yes	Yes		2nd order sequence
P. Berol. inv. 21236	Mars	$\Gamma?$	?	Yes	Yes	No		?
P. Oxy. LXI 4165a	Jupiter	Γ	?	Yes	Yes	Yes		2nd order sequence
PSI XV 1492	Saturn	Γ	Yes	Yes	Yes	Yes		2nd order and linear
P. Oxy. LXI 4166	Saturn	Ψ, Ω	No	Yes	Yes	Yes		2nd order and linear
E.E.S. inv. 79/1 (1)b	?	?	?	Yes	Yes	Yes		2nd order sequence

Table 5

From a Template for Saturn: P. Oxy. 4166 with restored columns

T'	ΔB	B'	T'	B'
90	0;6,23,27,16°	5;8,10,54,0°		0;46,40°
	0;6,27,27,16°	5;14,38,21,16°		0;53,20°
	0;6,31,27,16°	5;21,9,48,32°		1;0,0°
	0;6,35,27,16°	5;27,45,15,48°	10	1;6,40°
	0;6,39,27,16°	5;34,24,43,4°		1;13,20°
95	0;6,43,27,16°	5;41,8,10,20°		1;20,0°
	0;6,47,27,16°	5;47,55,37,36°		1;26,40°
	0;6,51,27,16°	5;54,47,4,52°		1;33,20°
	0;6,55,27,16°	6;1,42,32,8°	15	1;40,0°
	0;6,59,27,16°	6;8,41,59,24°		1;46,40°
100	0;7,3,27,16°	6;15,45,26,40°		1;53,20°
	0;7,7,27,16°	6;22,52,53,56°		2;0,0°
	0;7,11,27,16°	6;30,4,21,12°		2;6,40°
	0;7,15,27,16°	6;37,19,48,28°	20	2;13,20°
	0;7,19,27,16°	6;44,39,15,44°		2;20,0°
105	0;7,23,27,16°	6;52,2,43,0°		2;26,40°
	0;7,27,27,16°	6;59,30,10,16°		2;33,20°
	0;7,31,27,16°	7;7,1,37,32°		2;40,0°
	0;7,35,27,16°	7;14,37,4,48°	25	2;46,40°
	0;7,39,27,16°	7;22,16,32,4°		2;53,20°
110	0;7,43,27,16°	7;29,59,59,20°		3;0,0°
				3;6,40°
				3;13,20°
				3;20,0°

on day 0 again $B = 0^\circ$. The total progress in the two intervals is $7;30^\circ$ (effectively) and $3;20^\circ$ respectively, both quantities being parameters associated with the "slow zone" of System A in Babylonian texts. It appears likely that this template was designed to be used with epochs for each of Saturn's "Greek letter" phenomena computed by System A, on the condition that the epoch longitude was in the slow zone. There would have been an analogous template associated with the fast zone.

Remarks on Individual Texts

P. Oxy. 4162. Template for the sun. This is the only template that is not based on arithmetical methods. The longitudes are computed trigonometrically from the Hipparchus-Ptolemy solar model, or something very like it.

Day 0 corresponds to the sun's passage of its perigee, at longitude Sagittarius 13;30°, which is equivalent to Ptolemy's perigee adjusted to the convention that the vernal equinoctial point is at Aries 8° instead of Aries 0°. This table and the next are discussed in Jones 1997b.

P. Oxy. 4163. Template for the sun. The scribe used the vacant space around the end of the table to copy a procedure text concerning the computation of syzygies, with an example for A.D. 259/260. Day 0 is summer solstice, at Cancer 0°. The longitudes in the preserved portion of the table are computed using long stretches of linear motion.

PSI 1493. Template for the moon. Unpublished; an edition with commentary by Neugebauer was prepared in 1964 for inclusion in volume 15 of the *Papiri della Società Italiana*, which has yet to appear. A partial translation was provided by Neugebauer 1975, 823. Like the other lunar templates *P. Oxy.* 4150, 4164, and 4164a, this table belongs to the Standard Scheme, for which see Jones 1996a. 4150 and 4164 are on the other sides of Standard Scheme epoch tables.

P. Oxy. 4217 and 4217a–c. Templates for Mercury. These are actually series of templates for Mercury's intervals of visibility, capable of bridging any interval of a whole number of days within certain limits. Because the columns progressively increase or decrease in length by 1, the general appearance of the table is triangular or trapezoidal. (The intervals of invisibility were probably represented by linear motion.)

P. Berol. inv. 21236. Template for Mars. Published in Neugebauer and Brashers 1976, where it was identified as an "ephemeris," that is, daily longitudes associated with specific dates. In fact it is clearly a template, with the conventional column for ΔT at five-day intervals, and an initial longitude of 0° exactly on day 0 (the longitude for day 1 should be read 0;34°, not 0;31°). The heading "Cancer" shows that the template is meant to be used with epochs in this sign—that is, in the slowest zone of the ecliptic for this planet—and the longitudes fit the beginning of the interval of motion starting with Γ .

PSI 1492. Template for Saturn. Unpublished, the prospects for publication being the same as for *PSI* XV 1493 above. Part of the table was translated in Neugebauer 1975, 791.

P. Oxy. 4166. Template for Saturn. The template is written on the back of a document. In the space between two columns of the document, in the same hand as the table, are a few lines of jottings or calculations involving the parameters of the template.

E.E.S. inv. 79/1 (1)b. Published in Jones 1998c. A badly damaged table containing a second-order sequence of sexagesimals in the format of a template. The astronomical meaning of the numbers has not been identified.

Table 6
Manuscripts of Ptolemy's *Handy Tables*

Text	Codex?	Tables preserved (in part)
<i>P. Oxy.</i> LXI 4167	No	Oblique ascensions; anomaly table; planetary latitudes; stations; phases; greatest elongations
<i>P. Oxy.</i> LXI 4168	Yes	Declinations & lunar latitude; solar & lunar mean motions; parallax; planetary anomaly; unidentified supplementary tables
<i>P. Oxy.</i> LXI 4169	Yes	Planetary anomaly
<i>P. Oxy.</i> LXI 4170	Yes	Anomaly table; planetary mean motions
<i>P. Oxy.</i> LXI 4171	Yes	Oblique ascensions

4.3 Handy Tables and Other Kinematic Tables

Under this head we group various tables that do not strictly conform to a single format, but that, in Ptolemy's phrase, "exhibit the uniform circular motion" of kinematic models for the heavenly bodies through mean motion tables and anomaly tables. This is of course Ptolemy's own approach. And since Ptolemy published his mean motion and anomaly tables as part of a larger collection of tabular material (at first interspersed among the chapters of the *Almagest*, then independently as the *Handy Tables*) that by and large defined for a millenium of later astronomers what should go into a set of tables, we also include here any papyrus tables that are related to the other parts of the Ptolemaic corpus.

Fragments from several copies of Ptolemy's *Handy Tables* survive on papyrus (table 6). Of the major divisions of the collection as it is known to us from Byzantine manuscripts and the manuals of Ptolemy and Theon, almost all are represented on papyrus, including sections such as the tables for planetary "Greek-letter" phenomena that one suspects were seldom used. Most of these ancient manuscripts were codices, and the "look" of the page is often close to the medieval copies.

Remarks on Individual Texts

P. Oxy. 4167. This is the only known copy of the *Handy Tables* in roll form. It was a handsome manuscript, almost certainly in several rolls, for the 30 meters or so required for the full set of tables would have been unmanageable unless divided into smaller sections. The numerous extant fragments come from scattered parts of the *Handy Tables*: the spherical astronomy toward the beginning; tables for planetary latitudes, stations, greatest elongations, and visibilities towards the end; and a small fragment of one of the anomaly tables (it is not clear whether the one for the sun and moon or part of the planetary

set). Aside from particular readings, the divergences from the medieval text are comparatively slight: omitted index columns in the oblique ascensions, and a superfluous column of zeros in the planetary latitudes. The fragments of 4167 were found in several folders of the unpublished Oxyrhynchus papyri, interspersed with many other bits of tables—almost certainly the remnants of an astrologer's library discarded *en masse*. Among the other tables in this archive were arithmetically-based epoch tables (4153–4155, 4159) and templates (4165, 4217a–c) as well as other kinematic tables (4169, 4173a) and almanacs covering dates from the early third to the first decade of the fourth century A.D.

P. Oxy. 4168. The tables preserved from this codex are, taken singly, almost identical to their counterparts in the medieval copies, but there were some differences in the sequence of tables. For example, the parallax tables begin on the verso of the table for solar declination and lunar latitude, whereas in the medieval manuscripts the eclipse tables and others come between. Other bits in the same hand, and presumably from the same manuscript, do not belong to the *Handy Tables* as we know it; one of these was part of a geographical table of uncertain purpose and structure.

P. Oxy. 4170. Seemingly part of a page from a codex; but if so, the arrangement of the tables was peculiar. On one side is the *second* page of the planetary mean motions (25-year intervals for Mars, Venus, and Mercury); on the other, the last page of an unidentified anomaly table.

While the *Handy Tables* clearly had a wide diffusion, Ptolemy's earlier versions of the tables in the *Almagest* have not so far turned up on papyrus (nor have any fragments of the text of the *Almagest* been identified). There are, however, papyrus tables that are based on the astronomical parameters set out in the *Almagest*, but presented in a form that is not known to be due to Ptolemy, as well as tables that present apparently non-Ptolemaic data within the distinctive structure of certain of Ptolemy's tables (table 7). Leaving aside the improbable hypothesis that these were versions Ptolemy himself published but that did not survive through the medieval manuscript tradition, either the resemblances are due to Ptolemy's adhering to established tradition, or they reflect others' attempts to improve on Ptolemy. In my opinion the latter is the more likely explanation for all but the chronological tables.

Remarks on Individual Texts

P. Ryl. 522/523. (Photograph of 522 in plate 4 of *P. Ryl.* III.) One side of this fragment of a codex page, published as *P. Ryl.* 522, contains part of the first two columns from a table of noteworthy cities, essentially the one of the *Handy Tables* but with variants from the (itself rather unstable) medieval text.

Table 7

Other tables related to Ptolemy's tables

Text	Codex?	Tables preserved (in part)
<i>P. Ryl.</i> III 522/523	Yes	Noteworthy cities; oblique ascensions
<i>P. Lond.</i> III 1278	Yes	Geographical table; geographical latitudes and longest daylight; right ascensions and equation of time; oblique ascensions; planetary mean motions, with column of unknown significance
<i>P. Oxy.</i> LXI 4173	Yes	Planetary mean motions
<i>P. Oxy.</i> LXI 4173a	Yes	Anomaly? and others?
<i>P. Oxy.</i> LXI 4172	No	Planetary phases?
<i>P. Oxy.</i> I 35	No	Regnal canon with lengths of reigns but no totals, Augustus to Decius (A.D. 249)
<i>P. Oxy.</i> XXXI 2551	Yes	Regnal canon with lengths of reigns but no totals, Cyrus to Philip (A.D. 243); procedure text
<i>P. Ryl.</i> I 27	No	Regnal canon with lengths of reigns and totals (eras Augustus and Commodus), Commodus to Gallus (A.D. 250); procedure text

The columns on this side were of approximately 45 lines. The other side (*P. Ryl.* 523) has the end of a table of oblique ascensions, based on the same parameters as the one in the *Handy Tables* but with minor numerical deviations in the minutes. The table was laid out in a different format from the *Handy Tables*, in such a way that each page contained the ascensions for the thirty degrees of one zodiacal sign for three *climata*; and there is no column for the number of equatorial degrees rising in one seasonal hour. The preserved part is from the last page (Pisces, *climata* 4–6), so that in the original codex this was the recto.

P. Lond. 1278. Published in Neugebauer and T. C. Skeat 1958. Fragments from two codices, or one codex written by two scribes. In the first hand are parts of (1) a geographical table; (2) a table relating maximum length of daylight to geographical latitude; (3) a table for right ascension, sine of right ascension, and equation of time normed for the Era Nabonassar; and (4) oblique ascensions and rising times of 10° arcs for the seven *climata*. Although all these tables are derived from the parameters of the *Almagest*, none seems to have formed part of the original *Handy Tables* as described by Ptolemy in his introduction to that work. Nevertheless versions of (1), (2), and part of (3) are found in some of the medieval copies of the *Handy Tables*. In the second hand is a fragment from a table of mean motions for Saturn, laid out in the format of the *Handy Tables*, with 25-year intervals counted from the Era

Philip. From the table of mean motions at 25-year intervals we have a column for the planet's mean motion in longitude reckoned from the apogee, as in the *Handy Tables* but with one more fractional place, and a column for the planet's mean motion in longitude reckoned from Aries 0° , which is not found among Ptolemy's tables. On the other side of the fragment is the table of mean motions at 1-year intervals, with a column for Saturn's mean motion in anomaly, again to one more fractional place than in the *Handy Tables*, and a mysterious column with quantities increasing by 155;23,30 per line.

P. Oxy. 4173. Tables of mean motions of Regulus and the five planets for the Egyptian months and days. The calendrical structure of the table is that of the *Handy Tables*, but the mean motions are given to one more sexagesimal place, and as far as they go they are in exact agreement with the parameters of the *Almagest*. The table is also un-Ptolemaic in presenting only one mean motion for each planet: for Saturn, Jupiter, and Mars, the mean longitude; for Venus and Mercury, the mean anomaly.

P. Oxy. 4173a. Tables in a hand similar or identical to that of 4173; there is no other evidence that they were parts of the same manuscript. Most of the fragments are from tables that were very similar in structure to the anomaly tables of the *Handy Tables*, with a double column of arguments ascending from 1° and descending from 360° at 1° intervals (30° to a page), and several columns of dependent functions. The numbers in these columns do not match any of Ptolemy's anomaly tables, and I have not succeeded in identifying them.

P. Oxy. 4172. The tables in the papyrus look, at least superficially, like the planetary visibility tables of the *Handy Tables*; but there is no specific match. I am very unsure of this identification.

There remain a few tables—surprisingly few—that point to the existence of traditions of kinematic modeling that owed little, if anything, to Ptolemy (table 8).

Table 8
Other kinematic tables

Text	Codex?	Tables preserved (in part)
P. Oxy. LXI 4174	Yes	Lunar mean motion
P. Oxy. LXI 4174a	No	Solar mean motions (longitude, anomaly, latitude)
P. Oxy. LXI 4220	Partly	Lunar mean motions; anomaly?
P. Oxy. LXI 4223	No	Sinusoidal function (anomaly?)
P. Oxy. LXI 4224	No	Sinusoidal function (anomaly?)

Remarks on Individual Texts

P. Oxy. 4174. A rather crude table. On one side is a table of lunar mean longitudes, in integer degrees, for the beginnings of a series of Alexandrian years. On the other side are supplements of lunar mean motion in longitude for the single days of a year, again without fractions.

P. Oxy. 4174a. Mean motions of the sun, tabulated for the days of a calendar month and for equinoctial hours. Three independent motions are given, which correspond approximately to periods of $365\frac{1}{4}$, $365\frac{1}{2}$, and $365\frac{1}{8}$ days. A passage in Theon of Smyrna (ed. Hiller, p. 172) allows us to identify these as the sun's mean motion in longitude, anomaly, and latitude according to a theory of unknown provenance.

P. Oxy. 4220. Fragments from, apparently, two manuscripts. The two fragments of the first manuscript, written on one side of the papyrus only, belong to a table for the mean motion of the moon's apogee in sidereal longitude for Egyptian years, and a table for the mean elongation of the moon from the sun for single days. The other fragment, from a codex, is from what seems to be an anomaly table. The numerals in one of the preserved columns reach a maximum value of 47;0 and then decrease (Venus's synodic anomaly?).

P. Oxy. 4223. A table with sets of columns of 45 lines, each comprising an index number (increasing by steps of 1) and a corresponding quantity with one sexagesimal fractional place. At index number 96, a maximum of 7;30 is attained, after which the numbers decrease, evidently approaching zero at or near index 180. The pattern suggests a simple table of equations.

P. Oxy. 4224. The table is roughly like 4223 in structure, with an index column and a column of corresponding quantities with two fractional places. A maximum, 19;24,19, seems to occur at index 98, after which the numbers decrease with more or less constant second differences. Extrapolation suggests again that zero was reached near index 180.

5 ALMANACS

5.1 Ephemerides

The name "Ephemeris" was applied already in antiquity to a table that listed the positions of the heavenly bodies at intervals of one day, and it is desirable to restrict the term to this meaning.¹¹ Ephemerides (table 9) are laid out according to a civil calendar, either the Alexandrian or the Roman, with a set of columns for each month and one line for each day of the month. The leftmost columns of each set are used for the day numbers in the principal calendar of the ephemeris and in one or more other calendars. After these follow columns containing longitudes of the heavenly bodies and other data such as syzygies. Some ephemerides also

Table 9
Ephemerides

Text	Years	Codex?	Calendar	Almanac?	Columns in ephemeris
<i>P. Oxy. LXI 4175</i>	24 B.C.	No	Alexandrian	Yes	Roman, Alexandrian calendars; moon
<i>P. Dublin TCD F.7</i>	100	No	Roman?	No	... planets; ...
<i>P. Oxy. LXI 4176</i>	111	No	Alexandrian	Yes	... moon; time of moon's sign-entries
<i>P. Oxy. LXI 4177</i>	121-127	No	Alexandrian	Yes	Alexandrian calendar; moon (only on dates of sign-entries)
<i>P. Harris I 60</i>	140	No	Roman	Yes	Planetary weeks; Roman, Alexandrian calendars ... moon?; ?
<i>P. Oxy. LXI 4181</i>	161	No	Roman?	No	Roman, Alexandrian, lunar calendars; moon; time of moon's sign-entries; ... planets
<i>P. Oxy. LXI 4177a</i>	245	No	Alexandrian	?	Moon; time of moon's sign-entries
<i>P. Oxy. LXI 4178</i>	261	No	Roman	?	Roman, Alexandrian, lunar calendars; moon; time of moon's sign-entries
<i>P. Oxy. LXI 4184a</i>	293	No	Alexandrian	No	Alexandrian calendar; moon ...
<i>P. Oxy. LXI 4179</i>	348	No	Roman	No	Roman, "Greek", Alexandrian, lunar calendars; moon; time of moon's sign-entries; syzygies; sun; planets
<i>P. Oxy. LXI 4180</i>	465	Yes	Alexandrian	No	... Roman, lunar calendars; evaluation of day; moon; sun; planets
<i>P. Mich. inv. 1454</i>	467	Yes	Roman	No	Weeks; Roman, Alexandrian, lunar calendars; moon; time of moon's sign-entries; sun; planets; evaluation of day
<i>P. Vind. inv. G. 29370b</i>	471	Yes	Roman	?	Weeks; Roman, Alexandrian, lunar calendars; moon; ...
<i>P. Vind. inv. G. 29370</i>	489	Yes	Roman	No	Weeks; Roman, "Greek", Alexandrian, lunar calendars; moon; ... planets; ascending node; evaluation of day
<i>P. Oxy. LXI 4182</i>	?	Yes	Roman	No	Roman, Alexandrian, lunar calendars; moon; ... planets; eval. of day?
<i>P. Oxy. LXI 4183</i>	?	Yes	Roman	No	Roman, Alexandrian, lunar calendars; ...?
<i>P. Oxy. LXI 4184</i>	?	No	?	?	... unknown calendar; moon ...
<i>P. Vind. inv. G. 3231</i>	?	Yes	?	No	... moon and lunar sign-entries; ... planets ...
<i>P. Berol. inv. 21240</i>	?	No	?	No	... sun; planets ...

have a column giving brief astrological appraisals of the auspiciousness of each day, apparently based on the data in the preceding columns. The time of day for which the longitudes in ephemerides were reckoned seems always to have been six equinoctial hours past noon.

The selection and order of the columns of data vary from one ephemeris to the next. Broadly, however, there are two kinds: ephemerides that have columns for each of the sun, moon, and five planets; and "almanac-ephemerides," in which the ephemeris proper only has a column for the lunar longitude while the progress of the planets is recorded above the ephemeris in a monthly almanac (see section 5.3 below). The almanac-ephemeris seems to be the older format. An anonymous text explaining in detail how to construct ephemerides of the later type is preserved in several medieval astronomical and astrological manuscripts.¹² It allows for the inclusion of some kinds of information, such as eclipse predictions and weather signs derived from fixed star phases, that have not so far appeared in the papyri.

Table 10 shows a hypothetical ephemeris, not based on any actual papyrus but covering the same month as *P. Oxy. 4176*. Here the first four columns give the date respectively in the Alexandrian, Roman, "Greek" (i.e., Roman, but counting the days forward as we do), and lunar (counting from conjunction). The next three columns belong to the moon, giving the zodiacal sign, degrees and minutes, and the time of crossing into a new sign in seasonal hours. The remaining six columns, giving the longitudes of the sun and the five planets, would be omitted in an almanac-ephemeris.

The five-day almanac *P. Heid. inv. 34* (see 5.4 below) also has a section giving daily longitudes of the moon, but as a continuous vertical series running through several columns rather than in ephemeris format.

Remarks on Individual Texts

Dublin TCD F.7. Published with photograph in F. A. J. Hoogendijk 1982; identified as ephemeris and dated in Jones 1995 (correcting false interpretation in Jones 1991).

P. Oxy. 4177. The arrangement differs from the other almanac-ephemerides (a) in having the monthly almanac laid out with columns for the planets and rows for the months, as in an independent almanac, and (b) in omitting all lines in the ephemeris on which the moon does not enter a new zodiacal sign.

P. Harris 60. Identified as almanac-ephemeris and dated in Jones 1994b.

P. Mich. inv. 1454. Published with photograph in H. D. Curtis and F. E. Robbins 1935.

Table 10
Ephemeris for Trajan 15, Choeac (Alexandrian calendar) = November/December, A.D. 111

Alex.	Roman	Greek	Lunar	Moon	Sign-entries	Sun	Saturn	Jupiter	Mars	Venus	Mercury
1	4	28	10	Υ		9:13	10:45	29:16	11:9	29:49	15:55
2	3	29	11			10:15	10:47	29:28	11:23	1:2	16:59
3	1	30	12	♄	N 1	11:17	10:49	29:40	11:37	2:15	18:5
4	Kal.	1	13			12:19	10:52	29:51	11:51	3:29	19:15
5	4	2	14	♈	N 10	13:20	10:54	0:3	12:7	4:42	20:30
6	3	3	15			14:22	10:57	0:15	12:22	5:54	21:45
7	1	4	16	♉	D 9	15:24	10:59	0:27	12:39	7:8	23:2
8	Non.	5	17			16:26	11:1	0:39	12:55	8:22	24:25
9	8	6	18	♊		17:28	11:3	0:51	13:15	9:34	25:48
10	7	7	19	♋	N 7	18:29	11:6	1:3	13:36	10:47	27:13
11	6	8	20			19:30	11:9	1:15	13:54	12:0	28:41
12	5	9	21	♌	D 11	20:32	11:12	1:28	14:14	13:14	0:9
13	4	10	22			21:34	11:15	1:41	14:33	14:27	1:41
14	3	11	23			22:35	11:19	1:54	14:53	15:40	3:14
15	1	12	24	♍	N 8	23:36	11:22	2:6	15:13	16:54	4:50
16	Id.	13	25			24:39	11:26	2:19	15:33	18:8	6:28
17	19	14	26	♎	D 3	25:41	11:29	2:32	15:53	19:22	8:6
18	18	15	27			26:42	11:33	2:45	16:13	20:35	9:46

Alex.	Roman	Greek	Lunar	Moon	Sign-entries	Sun	Saturn	Jupiter	Mars	Venus	Mercury
19	17	16	28	♏	D 7	27:43	11:37	2:58	16:35	21:49	11:27
20	16	17	29			28:44	11:40	3:10	16:57	23:2	13:8
21	15	18	1	♐	D 9	29:46	11:44	3:23	17:19	24:16	14:52
22	14	19	2			0:47	11:48	3:36	17:41	25:30	16:36
23	13	20	3	♑	D 10	1:49	11:52	3:49	18:3	26:45	18:22
24	12	21	4			2:51	11:56	4:2	18:27	27:58	20:7
25	11	22	5	♒	D 10	3:52	12:0	4:16	18:50	29:12	21:53
26	10	23	6			4:53	12:4	4:30	19:13	0:26	23:41
27	9	24	7	♓	D 12	5:55	12:8	4:43	19:36	1:40	25:29
28	8	25	8			6:56	12:13	4:56	19:59	2:54	27:18
29	7	26	9			7:57	12:17	5:10	20:24	4:8	29:7
30	6	27	10	♈	6 N	8:59	12:22	5:23	20:48	5:22	0:57

P. Vind. G. 29370 and 29370b. Published with photograph in H. Gerstinger and Neugebauer 1962. For the correct dates and identification of some of the columns, see Jones 1994c.

P. Vind. G. 3231. Published in Neugebauer and P. J. Sijpesteijn 1980b. The fragment preserves the headings of an ephemeris in codex format, as can be seen by comparison with *P. Oxy.* 4180–4182.

P. Berol. inv. 21240. Published in Ioannidou 1996, 144, and plate 62. The legible columns include the longitudes of the sun, Saturn, Jupiter, Mars, and Venus.

5.2 Sign-Entry Almanacs

"Sign-entry almanacs" record the dates on which each planet makes its crossings from one zodiacal sign to a neighboring sign. This is the most frequently encountered variety of table among the papyri (table 11), and was already recognizable as a standard type before arrival of the Oxyrhynchus material. The usual format is year-by-year and, within each year, planet-by-planet in the standard Greek order Saturn, Jupiter, Mars, Venus, Mercury. This sequence puts the planets in order of decreasing longitudinal and synodic periods, so that the number of sign-entries increases from one planet to the next. Sometimes the almanac is so arranged that each column starts a new year.

Each line of the almanac has three entries: the month (which may be omitted if it is the same as for the preceding line), the day of the month, and the sign entered. The month may be named or, more frequently, identified numerically by its sequence within the months of the Egyptian or Alexandrian calendar, starting with Thoth = 1. Similarly, the zodiacal signs are often represented as numbers in order of increasing longitude, starting with Virgo = 1.

In addition to the sign-entries, other events such as phases or stations may be recorded in the almanac, in which case the sign specified is the one *within which* the event occurs. The sign occupied by each planet on the first day of the year is often recorded in this way.

Two variants of the sign-entry almanac should be noted. In one group of almanacs from Oxyrhynchus, the date of nocturnal sign-entries is given as a double date (e.g., "16 17" signifies sign-entry during the night of the 16th leading into the 17th), and a fourth column of numerals follows the zodiacal sign. The numbers in this column, which never exceed 12, represent the time of sign-entry in seasonal hours. A further peculiarity of the four-column almanacs is that the sign-entries that they contain were apparently all computed using the *Handy Tables*. These almanacs

Table 11
Sign-Entry Almanacs

Text	Years	Calendar	Medium	Remarks
Tab. Amst. inv. 1	26 B.C.–24 B.C.	Egyptian or Alex.	Boards	Years in Callippic period
P. Berol. inv. 8279 (demotic)	17 B.C.–13 B.C.	Egyptian	Roll	
P. Laur. IV 144	69–75	Alexandrian	Codex	
Bodl. MS Gr. Class. F 7 (P)	98–103	Egyptian	Boards	Years in era Titus
Stobart Tablets (demotic)	70–133	Alexandrian	Boards	
P. Oxy. LXI 4185	129–133	Alexandrian	Roll	
P. Oxy. LXI 4189	136–144?	Alexandrian	Codex	
P. Oxy. LXI 4186	142–146	Egyptian	Roll	
P. Oxy. LXI 4187	160/161	Alexandrian	Roll	
P. Oxy. LXI 4188	161–165	Alexandrian	Codex	
P. Oxy. LXI 4193	195–203	Alexandrian	Codex	
P. Oxy. LXI 4188a	201–208	Alexandrian	Codex	
P. Oxy. LXI 4196	218–220	Alexandrian	Codex	Four-column
P. Oxy. XLVI 3299	217–225	Alexandrian	Codex	
P. Oxy. LXI 4190	241–243	Alexandrian	Codex	Four-column
P. Oxy. LXI 4191	236–245	Alexandrian	Codex	
P. Oxy. LXI 4192	276–280	Alexandrian	Codex	Four-column
P. Oxy. LXI 4194	282–286	Alexandrian	Codex	Four-column
P. Oxy. LXI 4195	300–304	Alexandrian	Codex	Four-column
P. Oxy. LXI 4196a	?	Alexandrian	Codex	Four-column
P. Strab. inv. gr. 1097 (ined.)	?	?	?	
P. Vind. inv. gr. 36041 + 26011 fr. n.	Perpetual	Alexandrian	Codex	
P. Oxy. LXI 4197	Perpetual	Alexandrian	Codex	
P. Oxy. LXI 4198	Perpetual	Alexandrian	Codex	

must have been a great trouble to produce—vain labor, to some extent, since the planetary tables of the *Handy Tables* cannot claim sufficient accuracy to justify searching for the precise hour of sign-entry.

Secondly, we have examples of perpetual sign-entry almanacs that give entries for an entire Goal-Year period for each planet in turn. These clearly follow the same principle of arrangement as the medieval “Almanacs,” where one used modulo arithmetic to locate a given year in each planet’s cycle in order to obtain the positions for that year.

Tables 12 and 13 allow us to compare the sign-entries from the same two Alexandrian years from a three-column and four-column almanac. In both, the sections ruled off below the regnal year contain the sign-entries for Saturn, Jupiter, Mars, and (in table 12) Venus, the rest of the almanac having been broken off at the bottom. Lost or illegible numerals are represented by “x,” but restorations that are certain have not been marked.

Remarks on Individual Texts

Tab. Amst. inv. 1. Published with photograph in Neugebauer, P. J. Sijpesteijn, and K. A. Worp 1977. Date established in Jones 1993. The years are numbered according to the (fifth) Callippic period, as I will show elsewhere.

P. Berlin 8279. Published with photographs in Neugebauer and R. A. Parker, *EAT* v. 3, 228–232 and plates 66–73.

P. Laur. 144. Published with photograph in R. Pintaudi and Neugebauer 1978, reproduced in P. Laur. v. 4. Corrected edition and dating of the back in Jones 1998b.

Bodl. MS Gr. Class. F 7 (P). Published with photograph in Neugebauer 1957; corrections and dating in Neugebauer 1972.

Stobart Tablets. Published with photographs in Neugebauer and R. A. Parker, *EAT* v. 3, 225–240, and plates 74–78.

P. Strasb. inv. gr. 1097. Unpublished; see Neugebauer 1975, 788.

P. Vind. G. 36041+26011 fr. n. Published with photograph in Neugebauer and P. J. Sijpesteijn 1980a; corrections and identification as perpetual almanac in Jones 1994c.

5.3 Monthly Almanacs

A “monthly almanac” (table 14) is a tabular almanac in which columns correspond to the months of the year, and rows to the planets, or vice versa; hence there is space for recording at least one planetary position for each planet for each month. A single entry comprises a day number

Table 12

Sign-entry almanac for Gordian 5–6 (A.D. 241–243) from P. Oxy. 4191

month	day	sign	month	day	sign
Year 5			Year 6		
1	1	12	1	1	1
2	1x	1			
6	1x	12	1	1	6
11	1	1	6	xx	7
1	1	5	1	5	3
6	2	6	3	14	4
			4	23	5
1	21	11	5	xx	6
6	17	10	7	6	7
7	17	11	8	xx	8
9	xx	12	9	xx	9
11	x	1	11	xx	10
12	25	2	12	29	11
1	11	1	1	8	1
2	2	2		27	2
	22	3	2	27	3
3	11	4	4	21	4
4	1	3	5	9	5
	21	4		26	6
5	17	5	6	13	7
6	x	6	8	16	8
	xx	7	9	2	9
(rest of column lost)				18	10
			10	7	11
			12	18	12
			epag.	x	1
			(rest of column lost)		

Table 13Four-column sign-entry almanac for Gordian 5–6 from *P. Oxy.* 4190

month	day	sign	hour	month	day	sign	hour
Year 5				Year 6 of Gordian			
1	1	12		1	1	1	
2	2	1	5	1	1	6	
7	7/8	12	5	6	16/17	7	6
10	30	1	5				
1	1	5		1	1	2	
6	5/6	6	1	2	2	3	3
				3	12/13	4	6
1	1	10		4	21/22	5	11
	23/24	11	x	5	30	6	5
5	10/11	10	x	7	8	7	11
7	10/11	11	x	(rest of column lost)			
9	17	12	x				
(rest of column lost)							

within the month, the planet's position on that day, and sometimes an indication of an event (e.g., sign-entry, station, or first appearance) to which the date and position apply. Whether a planet's progress through the year is to be read across a row or down a column is a matter of convenience of layout. When a monthly almanac is laid out above a lunar ephemeris for the same year (see 5.3 above), the planets are usually assigned rows so that the planetary positions for any month can be read directly above the ephemeris entries for the same month. On the other hand, most independent monthly almanacs assign the columns to the planets, to allow a wider space for the tabular entries. In addition, we have monthly almanacs for single planets.

The monthly almanacs fall into two groups in another way. A simpler format records, for a given planet and month, either (1) the day of the month on which the planet makes a sign-entry, with the newly occupied sign identified, or (2), if no sign-entry occurs during the month, the zodiacal sign occupied throughout the month. Such almanacs are close kin to sign-entry almanacs. A more elaborate kind reports the planet's phases and stations as well as sign-entries and gives the associated longitudes in degrees and even minutes; when nothing else happens to a planet during a month, the longitude on the first of the month is given. Such tables are

Table 14
Monthly almanacs

Text	Years	Calendar	Medium	Planets	Phases & degrees?	Remarks
<i>P. Oxy.</i> LXI 4199	14 B.C. –6 B.C.	Egypt. or Alexandrian	Codex	Jupiter only	Yes	
PSI inv. 75D + E.E.S. 79/82(1)	48–55	Egyptian	Roll	All (columns)	Yes	
<i>P. Berol. inv.</i> 21226	52–56	Alexandrian	Roll	Jupiter only	Yes	Years in era Augustus
<i>P. Nelson</i>	101–103	Alexandrian	Roll	All (columns)	Yes	Years in era Titus
<i>P. Tebt.</i> II 274	107–118	Alexandrian	Roll	All (columns)	No	Years in era Titus; new moons
<i>P. Lund V</i> 35b	119–122	Alexandrian	Roll	All (columns)	No	
<i>P. Oxy.</i> LXI 4201	126–128	Alexandrian	Codex	All (columns)	Yes	
<i>P. Oxy.</i> LXI 4202	152–155	Alexandrian	Roll	All (columns)	Yes	
<i>P. Oxy.</i> LXI 4203	215/216	Alexandrian	Codex	Saturn only?	Yes	
<i>P. Oxy.</i> LXI 4200	?	Alexandrian	Codex	Jupiter only	Yes	Unknown era
<i>P. Oxy.</i> LXI 4203a	?	Alexandrian	Roll	Mercury only	Yes	

Table 15Monthly almanac for A.D. 154/155 from *P. Oxy.* 4202

Month	Day	Saturn	Day	Jupiter	Day	Mars
I	[]	ⲙ []	[]	ⲙ 6° 23rd Γ 12°	1	/ 2;45°
II	[]	ⲙ []	x	ⲙ xx;7°	1	ⲟ 0;41°
III	[]	ⲙ xx;3x°	x	ⲟ 0;x°	13	ⲙ 0;37°
IV	[]	ⲙ xx;41°	1	ⲟ 1;x4°	26	ⲕ 0;3°
V	[]	ⲙ 21;35°	xx	ⲟ []	1	ⲕ 4;1x°
VI	[]	ⲙ 20;29°	[]	ⲟ []	7	ⲕ 0;38°
VII	[]	ⲙ 17;5x°	[]	ⲟ []	16	ⲟ 0;7°
VIII	[]	ⲙ 15;14°	1	ⲙ 26°	1	ⲟ 9;14°
IX	[]	ⲙ 12;x° Ψ	26	ⲙ 23;21° Ψ	3	ⲙ 0;4° 26th Ω 17°
X	[]	ⲙ 13;5°	6	ⲙ 24;21°	14	ⲟ 0;14°
XI	1	ⲙ 14;2°	1	ⲙ 26;47°	23	ⲟ []
XII	[]	ⲙ 20;57°	[]	ⲟ xx	5	ⲟ x;6° 2nd η 0°

potentially rich with information about the methods used to compute planetary motion; unfortunately none of the specimens known at present is in a good state of preservation. Table 15 shows one year's data for Saturn, Jupiter, and Mars from an almanac of this kind.

Remarks on Individual Texts

PSI inv. 75D + E.E.S. 79/82(1). Published with partial photograph in M. Manfredi and Neugebauer 1973; new fragment in Jones 1998c.

P. Berol. inv. 21226. Published in W. Brashear and Neugebauer 1983.

P. Nelson. Published in C. A. Nelson 1970; identified in Neugebauer 1971; date established by Jones, 1998b.

P. Tebt. 274. Published with photograph in Neugebauer 1942, 241–242.

P. Lund 35b. Published with photograph in E. J. Knudtzon and Neugebauer 1947.

5.4 Five-Day Almanacs

"Five-day almanacs" (table 16) are arranged like sign-entry almanacs, by year and within each year by planet in the standard order; but instead of sign-entries, the table records the planet's longitude (degrees and minutes) at five-day intervals starting with either the first or the fifth day of each month. Many more lines are needed for a year than in a sign-entry almanac, and a common arrangement is to have a column reserved for

Table 16

Five-day almanacs

Text	Years	Codex?	Remarks
<i>P. Oxy.</i> LXI 4212	217/218	No	
<i>P. Oxy.</i> LXI 4205	257/258	Yes	
<i>P. Oxy.</i> LXI 4206	272–274	Yes	
<i>P. Oxy.</i> LXI 4207	290/291	Yes	
<i>P. Oxy.</i> LXI 4208	295/296	No	
<i>P. Oxy.</i> LXI 4209	295/296	No	Stations included
<i>P. Oxy.</i> LXI 4210	300–302	?	
<i>P. Oxy.</i> LXI 4213	301/302	No	Same MS as <i>P. Oxy.</i> 4210?
<i>P. Oxy.</i> LXI 4211	306/307	Yes	
P. Heid. inv. 34	345–349	Yes	Also lunar longitudes and syzygies

each of the planets. The name of each month is written above the six lines required for its positions. Each line will give the day of the month, the zodiacal sign (this may be omitted if unchanged from preceding lines), and the degrees and minutes of longitude. As in sign-entry almanacs, the zodiacal sign is often denoted by its number, starting from 1 = Virgo. The specimen in table 17 is from the top of an almanac laid out with two columns per planet per year, so that the preserved portion has the beginning of the second half of A.D. 273/274 for Jupiter and the beginning of the first half of the same year for Mars.

All known five-day almanacs turn out to have been computed using the *Handy Tables*. The format is probably the ancestor of the medieval Almanacs, which also give planetary longitudes at five (or ten) day intervals; but no example of a perpetual five-day almanac employing the Goal-Year periods has yet come to light on papyrus.

Remarks on Individual Texts

P. Heid. inv. 34. Published with photograph in Neugebauer 1956; dating of lunar longitudes and syzygies in Neugebauer 1975 1056–1057.

5.5 Miscellaneous Almanacs

P. Oxy. 4204 is, so far, the only known specimen of a format that has some resemblance to the more detailed kind of monthly almanac. It covers the last six months of the Alexandrian year 54/55, recording, for each planet in turn (in the standard order), the dates and longitudes of its phases, stations, and sign-entries.

6 OTHER PAPYRI CONTAINING OR REFERRING TO TABLES

Although it is not the intention of this paper to provide a complete bibliographical index to the astronomical papyri,¹⁴ it nevertheless seems worthwhile, if only as a measure of the incompleteness of the foregoing classification, to draw attention to those tables on papyrus that do not fit into it. I omit fragments that are in too poor a state of preservation to offer much hope of recognition or analysis.

P. Carlsberg 31 (demotic). Published with photograph in Neugebauer and Parker, *EAT*, v. 3, 241–243, and plate 79A. Identified by A. Aaboe 1972 as an auxiliary table for a cycle of eclipse possibilities.

P. Heid. inv. 4144 + P. Mich. III 151. The joined fragments published with photograph in Neugebauer 1960. Interpreted in Jones 1990 as auxiliary tables for a variant of the System A scheme for Mars. I am no longer so sure of this, since the only similar table that has come to light, P. Oxy. 4216 (see below), does not fit into my reconstruction.

P. Oslo inv. 1336 (demotic). Published with photograph in Neugebauer and Parker, *EAT*, v. 3, 254–255, and plate 79C. A numerical table of unknown significance.

P. Ryl. III 526. A numerical table of unknown significance.

P. Oxy. LXI 4140. In the left of the two preserved columns, large consecutive (?) whole numbers (preserved: 571 and 572); in the right, a prose description of circumstances of some sort of event involving the moon's longitude, argument of latitude, and other unidentified elements.

P. Oxy. LXI 4216. A table of similar structure to P. Heid. inv. 4144 + P. Mich. 151.

P. Oxy. LXI 4218. Multiples of 5;0, 3;45, and 2;30, each up to 30;0.

P. Oxy. LXI 4219. A numerical table of unknown significance.

P. Oxy. LXI 4221. A table of longitudes, in one part increasing by constant 0;56,40° in Scorpio.

P. Oxy. LXI 4222. A table associating latitudes (?) with the twelve zodiacal signs: zero in Libra (and Aries?), maximum 7 southerly in Capricorn.

P. Oxy. LXI 4225. Index numbers up to 30, with three columns of small whole numbers exhibiting no apparent pattern.

P. Oxy. LXI 4226. Tables headed with names of planets; beside each of the zodiacal signs, one or two circular spots or eight-pointed stars in black or red ink.

P. Oxy. LXI 4228. Columns with second-order arithmetical sequences: (1) descending from 180 to 103;45,0; (2) ascending from 180 to 256;15,0; (3) descending from 360 to 256;15,0.

Lastly, there are several papyri containing prose texts that refer to tables:

P. Ant. III 141. A procedure text concerning computations of lunar longitudes, with methods closely related to P. Oxy. 4174; see Jones 1998b.

P. Ryl. I 27. Corrections to text, and translation, in Jones 1997a Appendix 2.

PSI XV 1490. Published in M. Manfredi 1966. Concerning the construction of mean motion tables for the sun and an anomaly (?) table for the sun.

PSI XV 1491. Unpublished (see above, section 4.2, on PSI 1493). Discussion in Neugebauer 1962, 388; 1975, 946; and Jones 1984—probably all incorrect.

P. Oxy. LXI 4136. Text on calculating the running totals of the Standard Scheme template.

P. Oxy. LXI 4142. Instructions for the *Handy Tables*: time conversions involving seasonal and equinoctial hours, geographical longitude, and the equation of time.

P. Oxy. LXI 4143. Instructions for the *Handy Tables*: the planetary latitude tables.

7 CONCLUDING REMARKS

At our present state of knowledge it seems appropriate to treat the astronomy of the papyri as a distinct "Greco-Egyptian" tradition with links not only to the Greek theoretical astronomy of Hipparchus and Ptolemy but also backward to the Babylonians and forward to the astronomers of Byzantium, Islam, and the Latin West. The debt to Babylonian astronomy is deep both in the kinds of things that Greco-Egyptian astronomy set out to accomplish and the methods that it employed. For example, the monthly almanacs give dates of the planets' sign-entries, dates and longitudes of their phenomena, and their longitudes at the beginning of each month—items that all are regularly reported in the Babylonian almanacs.¹⁵ Again, the planetary epoch tables on papyrus not only resemble ACT planetary tables in content, but were mostly computed using the same arithmetical procedures. On the other hand, the specific formats of the Babylonian texts do not reappear on papyrus, and many kinds of data prominent in the cuneiform texts (e.g., normal-star passages, and computations of lunar crescent visibility) are absent from the papyri. Between the two traditions we have to hypothesize a process not just of transmission but of profound transformation.

This had happened already by the beginning of the period for which we have good documentation, which roughly coincides with the

beginning of Roman rule in Egypt in the last decades of the first century B.C. From this time on, there is a remarkable uniformity in the kind of astronomy practiced in the papyri, and not merely at the superficial level of long-lived formats such as the ephemeris and the sign-entry almanac. One significant event that was certainly felt in Greco-Egyptian astronomy was the advent of Ptolemy's tables after A.D. 150, which apparently for the first time popularized kinematic methods of astronomical prediction. But even these did not instantly drive arithmetical methods out of use; instead, they inaugurated a period, which lasted at least two centuries, during which arithmetical and kinematic tables subsisted side by side. How much, besides the *Handy Tables*, survived out of this hotchpotch may become clearer by comparison of the papyrus almanacs and ephemerides with their medieval counterparts.

NOTES

1. See the account in E. G. Turner 1968, 17–41.
2. Neugebauer and van Hoesen 1959. The recent “aggiornamento,” Baccani 1992, places more emphasis on the horoscopes as astrological and social documents than on their astronomical aspect.
3. Jones, *APO*. I have especially to thank J. R. Rea and R. A. Coles for their untiring assistance in making these texts accessible to me, and to D. Fowler for bringing the Oxyrhynchus material to my attention in the first place.
4. Where possible I have used the abbreviations recommended in J. F. Oates et al. 1992 for Greek papyri. Papyri in published series are given in italics, with the volume (Roman) preceding the text number at the first reference. For bibliographical consistency the new texts edited in Jones, *APO* are referred to as *P. Oxy. LXI 4133–4300a*, although only a provisional list of their contents was included in vol. 61 of *The Oxyrhynchus Papyri*. For publication data of other papyri listed in the tables, see Appendix B of Jones, *APO*.
5. For a fuller discussion of the problems of establishing the provenance and identity of the users of the astronomical papyri, see Jones 1994a.
6. The prevalence of astrology in Roman Egypt is directly witnessed by numerous personal horoscopes and fragments of astrological treatises on papyrus, and the majority of the astronomical papyri too may be counted among the astrologers' papers.
7. This general definition of “almanac” embraces the medieval Arabo-Latin Almanacs as well as the varieties of cuneiform text that A. Sachs has named “almanacs” and “normal-star almanacs.”
8. The early history of the Egyptian calendar reform is disputed. A regular four-year cycle of intercalations was unquestionably followed after A.D. 8.

9. Jones 1997a.
10. Jones 1998a.
11. In the context of Babylonian astronomy the term has been applied, confusingly and imprecisely, both to the kinds of text later renamed by Sachs as “almanacs” and “normal-star almanacs” (e.g., by Kugler) and to the “ACT” numerical tables (e.g., by Neugebauer).
12. Neugebauer 1975, 1055–1056.
13. Parker 1950; Jones 1997c; Depuydt 1998.
14. A bibliographical checklist of published astronomical papyri appears as Appendix B in Jones, *APO* (bringing up to date Neugebauer 1962).
15. Sachs 1948, 277.

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P. Harris = *The Rendel Harris Papyri*.

P. Oxy. = *The Oxyrhynchus Papyri*.

P. Ryl. = *Catalogue of the Greek Papyri in the John Rylands Library, Manchester*.

PSI = *Papiri della Società Italiana*.

P. Tebt. = *The Tebtunis Papyri*.

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11

THE ROLE OF OBSERVATIONS IN PTOLEMY'S LUNAR THEORIES

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Ptolemy's lunar theory in the *Almagest* has been described from several points of view by previous scholars, though their emphasis has been on mathematical detail. It is our primary goal to build upon these previous studies and to focus on the way Ptolemy appealed to observations as part of his argument. A secondary and related goal is to characterize Ptolemy's use of earlier observations and his attitude to earlier theories. Our analysis depends on a methodology according to which reports, quotations, and analytical accounts of earlier works are accepted as authentic evidence for the state of astronomy prior to the date of the texts in which they are embedded only under special circumstances.¹ Ideally, acceptance should, in our view, be predicated on independent confirmation, or at least support, that is demonstrated by recourse to extant texts from the antecedent period. But, should this not be possible because the relevant earlier sources are lacking, we think that acceptance must wait upon credible argument that is made case by case and looks critically to the question of the reliability of other citations in the later texts. On this basis, we argue that there is no credible evidence for a Greek geometric lunar theory prior to Ptolemy that was used to compute lunar positions. Nevertheless, there is considerable evidence for lunar theories dependent on Babylonian arithmetic schemes prior to Ptolemy and, we suggest, there is reason to believe that Ptolemy was aware of them. It has often been said that Ptolemy's first lunar theory was already available to (if not invented by) Hipparchus (second century B.C.), but our analysis of the evidence casts doubt on that claim.

Ptolemy presents two theories to account for the lunar motion in longitude which we designate the first and the second lunar theories.² The first was posited by Ptolemy as the definitive theory for determining the position of the Moon at syzygy (conjunction and opposition of the Moon with the Sun); the second, for determining lunar positions when the elongation from the Moon to the Sun is not equal to 0° or 180°. At elongations 0° and 180° the second theory reduces to the first theory.