Two Astronomical Tables: P. Berol. 21240 and 21359

The two papyri edited below are part of the collection of the Ägyptisches Museum, Berlin. A description and provisional transcription of P. Berol. 21240 was published by G. Ioannidou with an excellent photograph.[1] I am grateful to Dr Wm. Brashear for informing me of P. Berol. 21359 and encouraging me to edit it.

1.

P. Berol. 21240 — Hermoupolis
2.7 × 16 cm — 2nd–4th century A.D.

The papyrus has writing only on one side, along the fibres, in a hand for which Ioannidou found parallels in the third century. Palaeographical dating for a small fragment consisting of almost nothing but numerals is of course less secure than for most documents, and as we shall see, the contents argue for a date in either the first half of the fourth century or the last half of the second century. The left part of the papyrus (about two fifths of its breadth) is so rubbed that one can only say with conviction that there was some writing there. My transcription disregards this part, and counts the columns of the table starting from the first transcribable column.

	i	ii	iii	iv	v	vi
1		]	ι̣ζ̣ . [			
2	[ ]β λ̣δ̣	ιδ λα	ις νθ	β λδ	κε κη	ς [
3	. με	ιε κθ	ις νδ	β λ	κς ε̣	ε̣ [
4	. .	ις κη	ις μη	β κς	κς̣ [ ]	. [
5	]	ι̣ζ̣ κς	εcπερ(ιος) [ις ι]γ̣	β κβ	κ̣[	

Notes:

iii 5. The two entries in this cell of the table are presumably meant to correspond to the single entries in the other cells of the same row.

vi 3. As we shall see, this column contains day-by-day longitudes of Venus, which can at the most increase by two or decrease by one in the degrees place from line to line. Epsilon is the only possible reading here.

Translation:

	i	ii	iii	iv	v	vi
1		]	17 x[			
2	[ ]2 34	14 31	16 59	2 34	25 28	6 [
3	x 45	15 29	16 54	2 30	26 5	5 [
4	x x	16 28	16 48	2 26	26 [ ]	x [
5	]	17 26	evening [16 1]3	2 22	2[x	

[1] G. Ioannidou, *Catalogue of Greek and Latin Literary Papyri in Berlin (P. Berol. inv. 21101–21299, 21911)*, Berliner Klassikertexte 11, Mainz, 1996, p. 181 and plate 62.

Numbers in Greek astronomical tables are most commonly written as a whole number followed by sexagesimal fractions, i.e. one or more numerals representing sixtieths ("minutes"), sixtieths of sixtieths ("seconds"), and so forth. Each numeral in a sexagesimal fraction can have a value from zero (represented by a special symbol $\bar{o}$) to 59. Since the second numeral of each pair in the table is always within this range, it is a good working hypothesis that the numbers represent units and minutes, and indeed most probably degrees and minutes specifying the longitudinal position of one or more heavenly bodies within zodiacal signs.

One of the most informative tools for investigating the mathematical structure and meaning of columns of numbers is to examine the line-to-line differences. In the present table we find that the numbers in column ii increase by 58, 59, and 58 minutes; those in column iii decrease by 5, 6, and 5 minutes; those in column iv decrease three times by 4 minutes; and those in column 5 increase once by 37 minutes. These rates of change are of the right order of magnitude for the daily longitudinal motion of the planets. If we wish to find a single heavenly body capable of progressing as quickly as just under 1° per day, and also capable of a retrograde motion of a few minutes per day, we are limited to Mercury and Venus. It would be difficult, however, to imagine a plausible arrangement of a table of positions for either of these planets that would lead to the specific pattern of fast and slow motion in the consecutive columns of the papyrus.

If, on the other hand, each column pertains to a different heavenly body, then we are dealing with an *ephemeris*, which is one of the more common standard formats for astronomical tables among the papyri of the Roman period.[2] The arrangement of columns in an ephemeris was fairly uniform. Each table presented the calculated positions of the heavenly bodies for a civil month (Egyptian or Roman), with rows corresponding to the consecutive days. The normal order of columns, from left to right, began with calendrical concordances, then the motion of the moon, then the sun, and then the five planets in the standard sequence Saturn, Jupiter, Mars, Venus, Mercury. The numbers in the papyrus can be reconciled with an ephemeris in only one way, but the fit is extremely good. Column ii must belong to the sun, which advances at a velocity between 58 and 59 minutes per day during two extended intervals of the year. Column iii is therefore Saturn, travelling retrograde at close to its maximum retrograde velocity (actually about 5 minutes per day). The indication "evening" in row 5 obviously marks Saturn's opposition with the sun, when it makes the transition from being above the horizon at sunrise to being above the horizon at sunset. The remaining columns iv–vi are respectively Jupiter (travelling retrograde at well under its maximum retrograde velocity), Mars (travelling direct at a very typical velocity), and Venus (travelling retrograde at an unknown velocity). Column i and part of the illegible preceding space must belong to the moon, but nothing definite can be made of this part of the table.

The dates for which a planetary table was calculated can often be determined along the same lines as the analysis of an undated horoscope. One begins by looking for dates when the heavenly bodies were actually inside or very near the zodiacal signs in which they are stated to be in the table, relying on the fact that ancient computations were generally accurate within a margin of a few degrees. In the present small fragment, however, no names of zodiacal signs are preserved. We may, however, make use of the following circumstances:

a. To account for the differences in column ii, the sun must be progressing at between 0° 58' and 0° 59' per day, which is intermediate between the sun's minimum velocity and its mean. This means that unless there was a serious defect in the computation of the sun's longitudes, the sun must have been in Leo, Virgo, Pisces, or Aries.

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[2] A. Jones, "A Classification of Astronomical Tables on Papyrus," in *Ancient Astronomy and Celestial Divination*, ed. N. M. Swerdlow (in press), section 5.1. For a similar case of identification, see A. Jones, "On the planetary table, Dublin TCD Pap. F. 7," *Zeitschrift für Papyrologie und Epigraphik* 107 (1995) 255–258.

b. Saturn is stated to be in opposition to the sun. The table is unlikely to be in error in this respect by more than a few days.

c. Jupiter and Venus are both moving retrograde, whereas Mars is in direct motion.

If we search in Tuckerman's tables[3] for dates within the range A.D. 100–400 that satisfy (or come very close to satisfying) these criteria, we find only the following three dates:

Date	*Sun*	*Saturn*	*Jupiter*	*Mars*	*Venus*
170 September 6 *daily motion*	Virgo 12° 31' 0° 59' 2"	Pisces 12° 23' –0° 4' 44"	Capricorn 7° 8' –0° 0' 18"	Leo 15° 47' 0° 37' 55"	Virgo 21° 6' –0° 30' 29"
276 April 15 *daily motion*	Aries 25° 21' 0° 57' 43"	Libra 25° 24' –0° 4' 30"	Sagittarius 22° 21' –0° 1' 44"	Leo 10° 0' 0° 19' 5"	Pisces 23° 4' 0° 4' 44"
332 March 12 *daily motion*	Pisces 22° 44' 0° 58' 44"	Virgo 22° 8' –0° 4' 37"	Virgo 3° 4' –0° 6' 36"	Taurus 21° 35' 0° 36' 36"	Pisces 11° 2' –0° 30' 0"

The second of these dates—the only one falling within the third century—is a poor fit. Venus has actually passed its period of retrogradation, while Jupiter has only just reached its first stationary point. A more serious discrepancy is the low velocity of Mars, which reflects the fact that it has recently completed its retrogradation; the velocity in the table is close to the planet's maximum velocity when it is in this part of the zodiac. This dating can, I believe, be confidently excluded.

The remaining two dates are both admissible. At the earlier date Jupiter was very near its second stationary point, so that its velocity was close to zero; the later date was near Jupiter's opposition, when its retrograde velocity is greatest. The velocity in the papyrus could be a mean value taken over the entire retrogradation, in which case it is consistent with either date. The solar velocity and the degree figures for the sun and planets on the whole agree best with the A.D. 332 dating.

2.

P. Berol. 21359 — Oxyrhynchus
12.5 × 7.9 cm — Cf. Plate IX — 3rd century A.D.?

A piece apparently from the lower left corner of an astronomical almanac, which when complete was either a rectangular sheet or a roll, written along the fibres. The hand is sloping with documentary forms, typical of astronomical tables of the third century.[4] The back is blank. 3 cm margin survives on the left side and (with slight variations in breadth) along the bottom. The other two sides are broken off. The original manuscript would have been about three times as tall as the extant fragment. The scribe apparently wanted all columns to end at about the same distance from the bottom edge of the papyrus, with the result that the entries in column ii are more closely squeezed together than the other columns. The end of each column is marked by a double horizontal stroke.

[3] B. Tuckerman, *Planetary, Lunar, and Solar Positions A.D. 2–A.D. 1649 at Five-Day and Ten-Day Intervals*, Memoirs of the American Philosophical Society 59, Philadelphia, 1964.

[4] E.g. *P. Oxy.* LXI.4193 in A. Jones, *Astronomical Papyri from Oxyrhynchus*, Memoirs of the American Philosophical Society, Philadelphia, 1999 (in press), a sign-entry almanac in codex form covering (at least) A.D. 195–203.

i			ii			iii		
	]	ε	[					
ς	.	ς̣	[α]	η	α		κ̣	ς
	κ	ζ		κη	β	ζ	ιη	ζ
ζ	θ	η	β	ιζ	γ	η	η	η
θ	ι	θ	δ	κα	δ		κγ	θ
	κε	ι	ε	ια	ε	θ	ι	ι
ι	ια	ια	ς	α	ς	ι	ζ	ια
ια	ς	ιβ		ιγ	ζ	ια	η	.
ι̣β̣	.	ια	η	ις	η		ις	ια
	ι̇θ	ιβ̣	θ	β	θ	ιβ	κθ	ιβ
				ιζ	ι		κζ	α
			ι	ς	ια			
			ιβ	ιη	ιβ			

Notes:

iii 10. The sequence of dates, month 12 (Mesore) 29 followed by 27, is impossible. It may be that the month number has been written one line too high; or the day number is incorrect.

Translation: see below.

The table is of a very well attested variety that I have designated as a *sign-entry almanac.*[5] For each of a series of consecutive years, the almanac lists for each of the five planets in turn the dates when it is calculated to cross from one zodiacal sign to a neighbouring sign. For example, in i 4, the table states that the planet in question entered the eighth zodiacal sign on the ninth day of the seventh month. The calendar is always the Egyptian, i.e. either the civil Egyptian calendar of the Roman period or the old unintercalated Egyptian calendar that persisted in use in astronomical contexts. Zodiacal signs are counted in their order of rising from Virgo = 1. Thus we can read i 4 as saying that the planet entered Aries on Phamenoth 9 according to whichever version of the calendar the almanac adheres to.

Each of the planets exhibits distinctive patterns of sign entries, and the near-monthly entries in the three columns of the papyrus are immediately recognizable as belonging to Mercury. This can be seen, among other things, from the occurrence, in all columns, of pairs of consecutive sign entries separated by fifteen days or less, which implies a velocity of at least 2° per day. It is apparent, then, that the almanac was laid out with one column for each year.

A possibly intentional consequence of the convention of counting the zodiacal signs from Virgo is that the sun is generally in the *n*th sign in the *n*th month *according to the reformed Egyptian calendar.* Since Mercury is never very far from the sun, a sign-entry almanac based on the reformed calendar will tend to have frequent entries for Mercury with the same month and sign number, whereas this will be true for an almanac based on the unreformed calendar only during the years when the two calendars were nearly coincident, i.e. in the late first century B.C. and early first century A.D. Our papyrus must employ the reformed calendar.

As a measure of the quality of the almanac, I present below the translated sign-entries alongside a series of Mercury's sign-entries computed using Ptolemy's *Handy Tables* for the years 228/229 through 230/231, during which Mercury exhibited a very similar pattern of motion.[6] The deviations are mostly

[5] Jones, "Classification" (see note 2), section 5.2.

[6] The calculations were performed by computer, with Ptolemy's tropical longitudes converted to sidereal longitudes by "Theon's formula," for which see O. Neugebauer, *A History of Ancient Mathematical Astronomy*, Berlin, 1975, 632–633.

small, except close to the retrogradations where the effects of different methods of computation are exaggerated. It cannot be assumed that these are the correct years for the almanac, because other equally good matches can be found within a palaeographically acceptable range of dates. Entries for minimum of two planets are needed to establish a unique dating for a sign-entry almanac.

Papyrus			*Handy Tables*		
col. i			228/229		
x	x	5	5	12	5
6	x	6	5	29	6
6	20	7	6	15	7
7	9	8	7	4	8[7]
9	10	9	9	10	9
9	25	10	9	26	10
10	11	11	10	12	11
11	6	12	11	1	12
12	x	11	11	28	11
12	19	12	12	16	12
col. ii			229/230		
1	8	1	1	3	1
1	28	2	1	21	2
2	17	3	2	9	3
4	21	4	4	17	4
5	11	5	5	5	5
6	1	6	5	21	6
6	13	7	6	8	7
8	16	8	8	15	8
9	2	9	9	2	9
9	17	10	9	18	10
10	6	11	10	5	11
12	18	12	12	13	12[8]
col. iii			230/231		
x	2x	6	6	20	6
7	18	7	7	20	7
8	8	8	8	8	8
8	23	9	8	24	9
9	10	10	9	10	10
10	7	11	10	1	11
11	8	x	10	19	10
11	16	11	11	17	11
12?	29?	12	12	6	12
12	27	1	12	23	1

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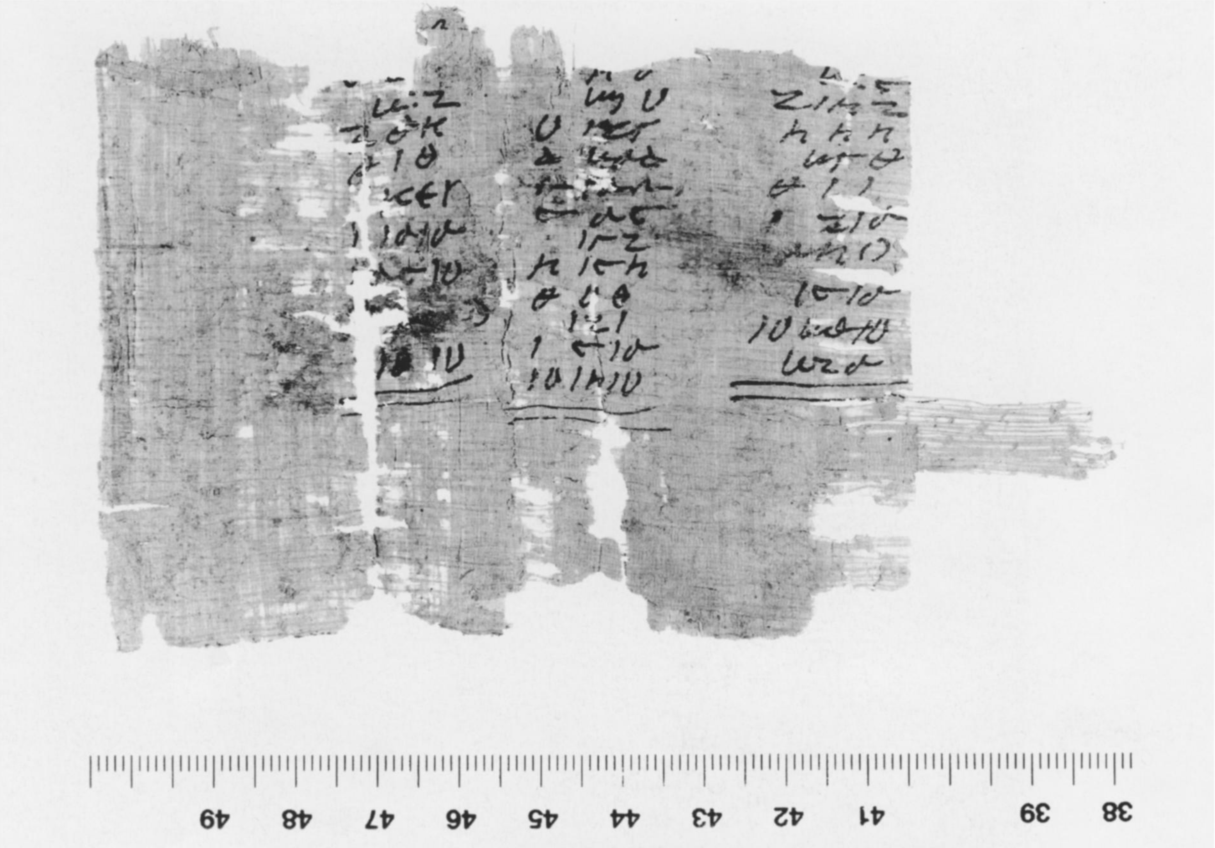
[7] According to the *Handy Tables*, Mercury dipped back into sign 7 (Pisces) between Pharmuthi 3 and 18. The papyrus does not register a corresponding retrograde sign-entry.

[8] The *Handy Tables* predict Mercury's next entry, into Virgo, on Epagomenae 1. In the papyrus, the corresponding entry must have been early in the following year.



P. Berol. 21359; A. Jones, pp. 201–205
Ägyptisches Museum und Papyrussammlung SMB. Photo: Margarete Büsing

Epitaph of the Bierzo District Museum, Detail (Photography of IMAGEN M.A.S.)
J.-M. Nieto Ibáñez, pp. 173–174