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An Astronomical Table Containing Jupiter's Synodic Phenomena

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An Astronomical Table Containing Jupiter's Synodic Phenomena

P. Berol. 16511 | Oxyrhynchus
9.5 × 9.7 cm | mid to late 1st c. A.D. (front) late 1st c. A.D. (back)

1. Description and transcription of the papyrus.

The fragment of papyrus edited here came from the same manuscript as a second fragment in the course of publication as *P. Oxy.* LXI.4160, which was found during Grenfell and Hunt's fourth season at Bahnasa (1905).[1] The presence in the Berlin collection of part of a *P. Oxy.* papyrus is paralleled by other known instances of parts of papyri excavated by Grenfell and Hunt finding their way to the dealers who supplied the German papyrus cartel, a phenomenon that Grenfell and Hunt attributed to "dishonest workmen." *P. Oxy.* 4160 does not directly join P. Berol. 16511, but belongs directly below it, with a gap of approximately 7.5 cm corresponding to thirteen missing lines in the astronomical table. The combined height of the two fragments in their original relative placement was about 28 cm, so that the complete manuscript was probably at least 30 cm tall. We will refer in this article to P. Berol. 16511 as fragment 1, and *P. Oxy.* 4160 as fragment 2 when discussing the table as a whole.

Fragment 1 is broken off on all sides but the top, and fragment 2 is broken on all sides. Both bear writing by a different hand on each side. It is impossible to determine by paleography which text was written first, although the natural presumption is that the writing on the side with horizontal fibers had precedence. On this side fragment 1 has an upper margin of 4.7 cm. The text is written in an elegant (but non-literary) documentary script of the mid to late first century A.D. Such words and phrases as διεξάγω, προσαγγέλλω, ἐν ψευδεῖ, ὁ φώρ (?) indicate the text most likely dealt with criminal court proceedings.

]ης τις διεξαξ ̣σ ̣[
Τ]οσαχμέως προσηγγελ[
] ̣ ̣ ̣[̣]ας ἐν ψευδ̣εῖ ̣[
]κέναι καὶ ὅτι ̣ ̣ ̣[
] ̣ ὁ φωρ[
- - - - - - - - - - - - - - - - - - -

1 διεξαξ ̣σ ̣[: a form of διεξάγω, a word which often has legal connotations. See, however, E. Voutiras, *Tyche* 1 (1986) 232.28, for another possible interpretation.

2 Τ]οσαχμέως: A village in the Heracleopolite nome attested from Ptolemaic through Byzantine times (e.g. *BGU* XIV 2436.4, 9; 2438.50; P. Heid. 301 II 15).

Nothing substantial can be read of the document on fragment 2.

On the side with vertical fibers in fragment 1 is an upper margin of 2.5 cm. The writing in black ink is in a small, rapid, cursive documentary style of the late first century A.D., which is consistent with the recording of regnal years as late as Vespasian 12 (A.D. 79) in fragment 2. Vertical separator lines block off the columns, and horizontal ones separate the individual entries. Some of the horizontal lines have been drawn twice, although this apparently has no significance for the table.

3 cm from the left edge and 1 cm above the uppermost horizontal dividing line, the letter alpha has been written in the margin. Further to the right, and only 0.3 cm above the same divider line, is a second

[1] Text and commentary in A. Jones, *Astronomical Papyri from Oxyrhynchus*, 2 vols., Memoirs of the American Philosophical Society, Philadelphia, 1999 (in press).

damaged and illegible marginal annotation with a horizontal stroke above it. The meaning of these notations is unclear, but in the light of our identification of the contents of the table it is possible that the alpha designates the columns below as pertaining to the first stations (of Jupiter).

Portions of five columns of the table are extant. From the first column of numerals on the left only line ends remain. On the right the entries are more well preserved. Each entry begins with the date in question, consisting of the L-shaped year-symbol succeeded by the number of the regnal year of the Roman emperor in question. (Generally the year numbers are consecutive, but see col. ii 1–2 for an exception.) Thereupon follow the month names, each succeeded by a series of numbers. The years in question can be determined thanks to the indication of the ruling emperors in col. ii 8 and 12, where respectively Gaius (Caligula) and Claudius are named. The regnal years of the unnamed emperor preceding these entries and ending in col. ii 7 with the 22nd year are obviously those of Tiberius. The entries in col. ii thus extend from A.D. 30 to 42. On the calendar in which the dates are expressed see below.

i	ii		iii	iv	v
	α				̣[
] κδ ια ιε			(ἔτος) ις	Μ[εϲ]ο(ρή)	[ι]θ νε ιβ ̣ [
]ϛ̣ ιε			(ἔτος) ιη	Θωύθ	κ λβ νδ κ[
] λ̣			(ἔτος) ιθ	Φαῶφ(ι)	κε β μγ [
] ̣δ ι̣ε			(ἔτος) κ	Ἁθύρ	κη η γ [
] κ ō			(ἔτος) κα	Τῦβι	ō ō κζ λ̣[
] ̣ ō ̣			(ἔτος) κβ	Μεχ[(είρ)]	ō μ̣α̣ νζ [
]γ̣ με̣	(ἔ̣τ̣ο̣ϲ̣) κγ τὸ `κ(αὶ)´		Γαίου	Φαμ[ε(νώθ)]	α νη [
]η με̣			(ἔτος) β	Φαρμο(ῦθι)	δ ι μ̣[
] ̣ λ̣			(ἔτος) γ	Παχώ(ν)	η μ[
		]	(ἔτος) δ	Π̣α̣ῦ̣ν̣ι̣	ι̣δ κ[
		]	Κλαυδ(ίου)	Ἐπείφ	κα̣ [
		]	(ἔτος) β	Μ̣[εϲο(ρή)]	κ̣ ̣ [

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Month names abbreviated by truncation, with last letter sometimes suspended. ἔτοϲ = ∟

2 *l.* Θώθ   8 το^κ   12 κλαυ^δ

col. i 5 and 6, and v 6 and 7: The symbol for zero is written as a small circle with a horizontal, slightly u-shaped stroke above it (in i 5 the reading is uncertain). This is one of the more common forms of this symbol, which is attested frequently in Greek astronomical papyri and medieval manuscripts, always in the context of sexagesimal numerals where it is frequently necessary to indicate zero units or an empty fractional place (on this notation, see note 5 below). Other forms of the symbol, for example a dot below—or even above—the horizontal stroke, render it unlikely that an abbreviation of a word such as οὐδέν is intended. See R. A. K. Irani, "Arabic Numeral Forms," *Centaurus* 4, 1955, 1–12; O. Neugebauer, *The Exact Sciences in Antiquity*, 2nd ed., Providence, 1957, 14; Jones, *Astronomical Papyri from Oxyrhynchus* (see note 1), Introduction, section 8.

col. ii: In all lines of the table except 8, there are small strokes, horizontal or leaning slightly upward to the right, along the left edge of the column. The purpose of these marks is unclear.

col. v 6: The last numeral on the right might be lambda (30) or the left half of my (40).

7: The first damaged numeral could be lambda rather than my.

8: Phamenoth 1 according to the (old) Egyptian calendar was February 10 in A.D. 37. However, Gaius' rule actually began thirty-seven days later on March 18. In astronomical tables the designation of the regnal year is purely schematic, normally referring to the emperor who was alive at the end of the year. This papyrus is atypical in providing a double designation of the year here, and probably also in line 12 where the beginning of the entry is broken off. In the continuation of the table, *P. Oxy.* 4160 line 10, the year preceding Vespasian 1 is assigned to Galba, who was usually left out of the regnal canons.

9: The last numeral on the right might be the left half of my (40) or else lambda (30).

13: The numerical pattern suggests that the small speck that is all that survives of the second letter was a zeta (7).

2. The structure and use of the astronomical table.[2]

P. Berol. 16511 + P. Oxy. 4160 is a planetary 'epoch table'. The existence of this variety of astronomical table was formerly conjectured from the fact that certain other tables ('templates') were known that listed a planet's daily progress relative to an epoch date and position, which would have had to be obtained from another source.[3] The first, and so far the only, planetary epoch tables to come to light are part of the very rich astronomical materials among the papyri excavated at Oxyrhynchus by Grenfell and Hunt. They will soon be published with the numbers P. Oxy. LXI 4152–4161.[4] The Berlin fragment (fr. 1) adds a substantial new piece to P. Oxy. 4160 (fr. 2), and the contents of both will be discussed below. We will limit ourselves here to the identification of the astronomical meaning of the dates and numbers in the papyrus, reserving the more technical analysis of the methods by which they were calculated to a separate article.

Each line in an epoch table represents a successive occurrence of one of the characteristic phenomena of a particular planet, such as its first or last visibilities, stations, or oppositions. The date of the event in the Egyptian calendar and the planet's corresponding longitude (zodiacal sign, degrees, and fractions of degrees in sexagesimal notation) are presented in parallel columns.[5] In the absence of preserved headings, we can identify which planet is concerned by the number of lines of the table that separate two lines in which the positions are close to each other in the zodiac, or in which the dates fall close to the same point in the year.

In our papyrus parts of two groups of columns survive. The left group, present only in fr. 1, consists of sexagesimal numerals, the probable meaning of which we will consider later. The right group consists of regnal years and Egyptian calendar month names, followed by numerals that are to be interpreted as a day number followed by a sexagesimal fraction of a day. The fraction may be thought of as a notional indication of the precise time of day of the phenomenon in question, expressed as sixtieths of the twenty-four hours starting with a conventional zero time (sunset?). Since, however, we find such fractions in epoch tables for phenomena like first morning visibility that can only occur at a specific time of day, the fractions are best treated as 'bookkeeping' required in the original determination of the dates but ignored for practical applications. We may also note that the thirtieth of a month is regularly

[2] A provisional text of fragment 1 (P. Berol. 16511) was studied by the late Udo Becker (Freiburg i. Br.), who established that the table was related to synodic phenomena of Jupiter. Independently, fragment 2 (*P. Oxy.* 4160) was discussed in A. Jones, "Studies in the Astronomy of the Roman Period: Planetary Epoch Tables," *Centaurus* 40, 1998, 1–41, esp. pp. 33–34, where it was shown to be a table of Jupiter's first stations, and tentative conclusions were drawn about the method by which the dates in the papyrus were computed.

[3] O. Neugebauer, *A History of Ancient Mathematical Astronomy*, Berlin, 1975, 791–792; A. Jones, "A Greek Saturn Table," *Centaurus* 27, 1984, 311–317, esp. p. 316.

[4] Jones, *Astronomical Papyri from Oxyrhynchus* (see note 1). A list of the papyri was included in vol. 61 of *The Oxyrhynchus Papyri*.

[5] Sexagesimal fractions in Greek astronomy consist of one or more numerals following the whole number part, and representing sixtieths, sixtieths of sixtieths, and so on of the unit. Each numeral may have a value from zero (written with the special symbol $\bar{o}$) to fifty-nine. When we are dealing with a number of degrees, as in a zodiacal position, the fractional places are the familiar minutes and seconds still in use. For clarity in translation we use a semicolon to separate the whole number from the fraction, and commas to separate the sexagesimal places.

denoted as day zero of the following month, a practice that is attested in two other epoch tables and that may have arisen by analogy with the counting of degrees in zodiacal signs from zero to twenty-nine.[6]

The positions corresponding to the tabulated dates have been broken off to the right in the papyrus. The dates themselves progress from line to line by intervals averaging a little more than a year and a month, returning from Mesore to Mesore after eleven lines (twelve years) in fr. 1, and similarly from like month to like month after the same numbers of lines and years in fr. 2. This periodicity is characteristic of the phenomena of Jupiter, since Jupiter's synodic period (the time it takes to return to the same elongation from the sun) averages about 398.89 days. Hence we can also infer that if the two fragments belong to the same series of dates, thirteen lost lines must have intervened between the last line of fr. 1 and the first of fr. 2. The assigned line numbers in the transcription reflect this fact.

Before determining which phenomenon of Jupiter the dates represent, we must decide which version of the Egyptian calendar was used. In the Roman period one would normally assume that dates in a papyrus belong to the reformed civil calendar ('Alexandrian'), in which three years of 365 days were regularly followed by an intercalary year of 366 days. In astronomical contexts, however, the old Egyptian calendar with its invariable years of 365 days continued in use because of its greater convenience for calculating exact time intervals; and in fact only one of the epoch tables known at present employs the Alexandrian calendar.

We can find out which calendar was used in our papyrus by the following reasoning. Eleven mean synodic periods of Jupiter amount to a little less than 4388 days, which is eight days more than twelve years in the old Egyptian calendar but only five days more than twelve Alexandrian calendar years. Now in the Ashmolean fragment there are several pairs of legible dates separated by twelve years (eleven lines), and the excess over whole calendar years is in each case seven or eight days. Moreover, whenever a date in fr. 2 comes twice or three times twelve years after a date in fr. 1, the excess over whole years is close to twice or three times eight days, not five days. Hence the calendar must be the old Egyptian (and incidentally we have also confirmed that fr. 2 continues the sequence of fr. 1).

Table 1 shows the dates in the papyrus converted into the Julian calendar, along with the dates of Jupiter's first station for the same years, calculated by interpolation from Tuckerman's tables. Obviously this is the phenomenon tabulated in the papyrus. The agreement is consistently within a margin of two days, which is quite good by ancient standards, considering the difficulty of establishing by observation the precise day when this slow planet reverses the trend of its motion.

We return to the identification of the column of numbers to the left of the dates of first stations in fr. 1. Most likely the complete table had sets of columns for several or all of Jupiter's synodic phenomena. If the cycle began, as usual, with first morning visibility, then one might have had columns from left to right for first visibility, first station, opposition, second station, and last visibility. The surviving numerals would probably be the degrees and sexagesimal fractions of the longitude of Jupiter at its first visibility.

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[6] P. Oxy. 4154 line 9 (Mesore 0;42, here an error for Epagomenae 0;42); P. Oxy. 4156a line 2 (Choeac 0;19).

*Index**	*Date in papyrus*	*Julian equivalent*	*Date of First Station*	*Difference*
	Tiberius			
1	16 XII 19	30 July 30	30 August 1	–2
2	18 I 20	31 September 4	31 September 6	–2
3	19 II 25	32 October 8	32 October 9	–1
4	20 III 28	33 November 10	33 November 9	+1
5	21 IV 30	34 December 12	34 December 10	+2
6	22 V 30	36 January 11	36 January 9	+2
	Gaius			
7	1 VII 1	37 February 10	37 February 8	+2
8	2 VIII 4	38 March 15	38 March 13	+2
9	3 IX 8	39 April 18	39 April 17	+1
10	4 X 14	40 May 23	40 May 22	+1
	Claudius			
11	1 XI 21	41 June 29	41 June 30	–1
1	2 XII	42 July–August	42 August 6	
	Nero			
4	4 IV	57 Nov–Dec	57 November 18	
5	5 V 14	58 December 20	58 December 18	+2
6	6 VI 15	60 January 20	60 January 18	+2
7	7 VII 16	61 February 19	61 February 17	+2
8	8 VIII 19	62 March 24	62 March 22	+2
9	9 IX 24	63 April 28	63 April 27	+1
10	10 X 30	64 June 2	64 June 2	0
11	11 XII 7	65 July 9	65 July 10	–1
1	13 I 9	66 August 15	66 August 16	–1
	Galba			
2	1 II 13	67 September 18	67 September 20	–2
	Vespasian			
3	1 III 18	68 October 22	68 October 22	0
4	2 IV 20	69 November 23	69 November 22	+1
5	3 V 21	70 December 23	70 December 22	+1
6	4 VI	72 Jan–Feb	72 January 22	
7	5 VII	73 Feb–March	73 February 22	
8	6 VIII 27	74 March 29	74 March 27	+2
9	7 X 1	75 May 2	75 May 2	0
10	8 XI 8	76 June 7	76 June 8	–1
11	9 XII 15	77 July 14	77 July 15	–1
1	11 I 17	78 August 20	78 August 21	–1
2	12 II	79 Sept–Oct	79 September 25	

Table 1. Dates in papyrus compared with dates of Jupiter's first station (modern theory)

(*Index situates each line in a recurring cycle of eleven, reflecting Jupiter's 12-year recurrence period.)

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