TWO ASTRONOMICAL PAPYRI REVISITED

1. *P. Vind.* G. 36041 + 26011 fr. n.[1]

In his commentary accompanying the edition of these fragments, O. Neugebauer identified them as belonging to a well-attested variety of planetary table, for which I have since proposed the name "sign entry almanacs". The dates of entry of each of the five planets into the zodiacal signs are recorded for a succession of years, so that it is easy to determine the zodiacal signs occupied by the planets for any specific date, say for casting a horoscope. Neugebauer correctly identified the planets to which most of the columns refer, but he did not succeed in establishing the structure of the original almanac. One difficulty is that the table is carelessly written and, in parts, rubbed, so that some of the numerals are easily misread. Hence the transcription misled Neugebauer into identifying two of the columns as giving dates of sign entry of the Sun, which appear in no other known almanac of this type; and this error naturally obscured the arrangement of the columns.

In the corrected transcription below, I have reversed the identification of the front and back of the fragments, for reasons that will appear subsequently, but I retain the labelling of the columns. In each tabular entry, the first numeral identifies the month (in either the Egyptian or Alexandrian calendar), counting from Thoth = 1; the second numeral is the day within that month; and the third numeral represents the zodiacal sign being entered on that day, counted in order of increasing longitude from Virgo = 1.

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[1] P.J. SIJPESTEIJN - O. NEUGEBAUER, *A New Version of Greek Planetary Tables*, *ZPE* 37 (1980) 285-293 and pl. XII.

Front (against the fibres, but lines below *kollesis* along fibres)

	L	M	N	O	P	Q	R
1						[ε] . [ε]	α α] α
2	]ζ̣ .	η ε η̣				[κ]δ̣ ς	α γ β
3	]η ε	κ̣θ̣ θ̣	δ κβ̣ δ	ια̣ κ̣η ιβ	η ιγ θ̣	ς ια ζ	γ̣ θ γ
4	]ε ς	θ κδ̣ ι	ε ιγ ε	ιβ κβ α	θ η ι̣	η ι̣η̣ η̣	κη δ
5	] . ζ	ι ιθ ια	ς ις ς	-ς	ι γ ια	θ ς θ	δ ιζ ε
6		ια ιδ ιβ	ς ι ζ	α α α̣	κ̣η ιβ	θ κα ι	ε γ ς
7		ιβ̣ η̣ α̣	ζ δ η	α̣ [. . β]		ι θ̣ ια	κ̣α̣ ε̣
8						ιβ̣ [. . ιβ	
9						ιγ̣ [. α	

Front, continued

	S	T
1		κ̣[. ς
2	ε ιθ ε	ς . [ζ
3	ς θ ς	η̣ ι̣[. η
4	ς κε ζ	θ . [θ
5	ζ ια η	θ . [ι
6	θ ιθ̣ θ	ι ζ̣ [ια
7	.	
8		
9		

Back (along the fibres)

	A	B	C	D	E	F	G
1				δ] ι̣α̣ [δ			
2				κ]η [ε			
3		γ κ δ̣	ε̣ [.] ς̣	ε̣ ι̣δ ς̣			ι̣β [. . ιβ
4		δ θ ε	ς ιζ ζ	ς ε ζ		κ]ς̣	κ̣η̣
5		ς ιζ ς	ζ̣ ς η̣	ς κδ̣ ς̣		α α ιβ	α α α
6	]ς̣	ζ γ ζ	η η ζ̣	ζ κα̣ ζ̣	δ ιγ ε	α ιβ α	ιθ β
7	ζ ι]η ζ	ζ ιθ η	η ιθ η	η θ η	ς κα̣ ς	β α β	β η γ
8	η]·ς η	θ ς θ	θ ια̣ θ	κ̣ς̣ θ̣	ζ η ζ	β̣ κβ γ	δ ις δ
9	κα . θ	ι ιγ ι	κ̣ . [ι]		ζ̣ κ̣δ̣ [η]	γ] ι̣ [δ	ε δ ε
10	θ] θ̣ ι						κ̣ [ς

Back, continued

	H	J	K
1			
2			
3			
4			
5	ζ ιβ ζ	η ε θ	ι[
6	ζ κη η	η ιθ η	ια[
7	η ιδ θ	θ ιθ θ	ιβ̣[
8	θ γ ι	ι η ι	
9	λ̣ θ̣	ι κδ̣ ια	
10		[ι]α̣ [. ιβ]	

To the transliterations which follow, I have added a column (δ) giving the intervals of days between successive dates of sign entry.

M	δ	N	δ	O	δ	P	δ
8 5 8							
(8) 29 9	24	4 22 4		11 28 12		8 13 9	
9 24 10	25	5 13 5	21	12 22 1	24	9 8 10	25
10 19 11	25	6 16 6	33			10 3 11	25
11 14 12	25	6 10 7	-6!			10 28 12	25
12 8 1	24	7 4 8	24				

Apparent speeds of 30° (one zodiacal sign) in 24 or 25 days are characteristic of Venus during its long stretches of fast motion relative to the sun; all four columns therefore presumably belong to that planet[2]. We may further expect that they pertain to four years in close sequence reading from left to right, but there is a possibility that a year or two may intervene between the preserved stretches because of the lost parts of the almanac. One way to check these intervals, and at the same time to correct the manifestly garbled column N, is to compute a similar almanac by ancient astronomical methods over a long interval, and search it for close matches to the sequences on the papyrus. I used for this purpose a computer simulation of Ptolemy's *Handy Tables*, applying Theon of Alexandria's formula for converting Ptolemy's tropical longitudes to the sidereal longitudes prevalent in the astronomical papyri. The resulting "ideal almanac" cannot be expected to coincide exactly with the dates in papyrus almanacs (which were probably computed by older, arithmetical methods rather than Ptolemy's tables), but discrepancies larger than two days or so should be rare except near the retrogradations of the planets.

Among several other possible dates, I found good matches for a sequence of years beginning with A.D. 378/379, as shown in the following table:

	Reconstructed Almanac		Papyrus	
	Date (Julian and Alexandrian)	Sign entered	Date	Sign entered
			Column M	
379	March 31 = VIII 5	Aries	VIII 5	Aries
	April 25 = VIII 30	Taurus	VIII 29	Taurus
	May 19 = IX 24	Gemini	IX 24	Gemini
	June 13 = X 19	Cancer	X 19	Cancer
	July 8 = XI 14	Leo	XI 14	Leo
	August 1 = XII 8	Virgo	XII 8	Virgo
			Column N	
380	December 18 = IV 22	Capricorn	IV 22	Sagittarius!
381	January 11 = V 16	Aquarius	V 13	Capricorn!
			VI 16	Aquarius!
	February 4 = VI 10	Pisces	VI 10	Pisces
	February 28 = VII 4	Aries	VII 4	Aries

[2] NEUGEBAUER identifies column P as belonging to the Sun, misled by incorrect transcriptions of three of the four preserved lines.

			Column O	
382	July 22 = XI 28	Leo	XI 28	Leo
	August 16 = XII 23	Virgo	XII 22	Virgo
			Column P	
384	April 9 = VIII 14	Taurus	VIII 13	Taurus
	May 3 = IX 8	Gemini	IX 8	Gemini
	May 28 = X 3	Cancer	X 3	Cancer
	June 22 = X 28	Leo	X 28	Leo

The agreement between recomputation and papyrus is so close that there can be no doubt that we have found the correct *relative* dating of these columns (*i.e.* one year missing between columns M and N and between columns O and P). The problem in column N seems to have originated in a "column slip" which was corrected (if that is the appropriate word!) by splitting the sign entry for V 16 into two separate entries.

Q	δ	R	δ	S	δ	B	δ
(5) 24 6		1 3 2		5 19 5		3 20 4	
6 11 7	17	3 9 3	66	6 9 6	20	4 9 5	19
8 18 8	67	(3) 28 4	21	6 25 7	16	6 17 6	68
9 6 9	18	4 17 5	19	7 11 8	16	7 3 7	16
9 21 10	16	5 3 6	16	9 19 9	66	7 19 8	16
10 9 11	18	5 21 5	18			9 6 9	47
						10 13 10	37

C	δ	D	δ	E	δ	F	δ
6 17 7		5 14 6		4 13 5		1 12 1	
7 6 8	19	6 5 7	21	6 21 6	68	2 1 2	19
8 8 7	32	6 24 6	19	7 8 7	17	2 22 3	21
8 19 8	11	7 21 7	27	7 24 8	16		

G	δ	H	δ	J	δ
1 19 2		7 12 7		8 5 9	
2 8 3	19	7 28 8	16	8 19 8	14
4 16 4	68	8 14 9	16	9 19 9	30
5 4 5	18	9 3 10	19	10 8 10	19
		9 30 9	17	10 24 11	16

All these columns show the same patterns of motion: progress through the signs at a maximum speed of 30° in 16 days, alternating with retrogradations that make the planet linger between 60 and 70 days in a zodiacal sign (sometimes also dipping backwards into the preceding sign). This behaviour is characteristic of Mercury[3]. Since four consecutive columns on one side of the papyrus have been shown to belong to Venus, followed by at least three consecutive columns belonging to Mercury, and moreover the entire other side seems also to belong to Mercury, it seems plausible to take the side bearing columns L through T as the front of the fragment, and the other side as its continuation. We would then have part of an almanac in which each planet's motion over several years was set out in turn, in the standard order Saturn, Jupiter, Mars, Venus, Mercury.

In order to confirm this hypothesis and to establish the actual intervals between the columns, I again searched the reconstructed "ideal" almanac for patterns that closely matched the figures on the papyrus. One such sequence of years begins in A.D. 301/302:

	Reconstructed Almanac		Papyrus	
	Date (Julian and Alexandrian)	Sign entered	Date	Sign entered
			Column Q	
302	January 19 = V 24	Aquarius	V 24	Aquarius
	February 5 = VI 11	Pisces	VI 11	Pisces
	April 13 = VIII 18	Aries	VIII 18	Aries
	April 30 = IX 5	Taurus	IX 6	Taurus
	May 16 = IX 21	Gemini	IX 21	Gemini
	June 2 = X 8	Cancer	X 9	Cancer
			Column R	
304	August 30 = I 2	Libra	I 3	Libra
	November 5 = III 9	Scorpio	III 9	Scorpio
	November23 = III 27	Sagittarius	III 28	Sagittarius
	December 10 = IV 14	Capricorn	IV 17	Capricorn
	December 31 = V 5	Aquarius	V 3	Aquarius
305	January 16 = V 21	Pisces	V 21	Pisces
			Column S	
307	January 15 = V 20	Capricorn	V 19	Capricorn
	February 2 = VI 8	Aquarius	VI 9	Aquarius
	February 17 = VI 23	Pisces	VI 25	Pisces
	March 6 = VII 10	Aries	VII 11	Aries
	May 12 = IX 17	Taurus	IX 19	Taurus
			Column T	
309	January 16 = V 21	Aquarius	(V) 2x	?
	February 2 = VI 8	Pisces	VI x	?
	April 10 = VIII 15	Aries	VIII 1x	?
	April 27 = IX 2	Taurus	IX x	?
	May 13 = IX 18	Gemini	IX x	?
	May 30 = X 5	Cancer	X 7	?
317	March 13 = VII 17	Pisces	(VII 1)8	Pisces
	March 31 = VIII 5	Aries	(VIII) 6	Aries
	April 15 = VIII 20	Taurus	(VIII) 21	Taurus
	May 2 = IX 7	Gemini	(IX) 9	Gemini
			Column B	
318	November 16 = III 20	Sagittarius	III 20	Sagittarius
	December 5 = IV 9	Capricorn	IV 9	Capricorn
319	February 11 = VI 17	Aquarius	VI 17	Aquarius
	February 27 = VII 3	Pisces	VII 3	Pisces
	March 15 = VII 19	Aries	VII 19	Aries
	April 1 = VIII 6	Taurus	IX(!) 6	Taurus
	June 7 = X 13	Gemini	X 13	Gemini
			Column C	
321	February 10 = VI 16	Pisces	VI 17	Pisces
	March 1 = VII 5	Aries	VII 6	Aries
	April 1 = VIII 6	Pisces	VIII 8	Pisces
	April 14 = VIII 19	Aries	VIII 19	Aries
	May 6 = IX 11	Taurus	IX 11	Taurus
	May 22 = IX 27	Gemini	(IX) 2x	Gemini?
			Column D	
322	December 7 = IV 11	Sagittarius	(IV) 11	Sagittarius?
	December 24 = IV 28	Capricorn	(IV 2)8	Capricorn?
323	January 10 = V 15	Aquarius	V 14	Aquarius

[3] Again, NEUGEBAUER'S attribution of column R to the Sun results from incorrect readings in the upper lines.

	January 30 = VI 5	Pisces	VI 5	Pisces
	February 17 = VI 23	Aquarius	VI 24	Aquarius
	March 17 = VII 21	Pisces	VII 21	Pisces
	April 5 = VIII 10	Aries	VIII 9	Aries
	April 21 = VIII 26	Taurus	(VIII) 26	Taurus
			Column E	
324	December 8 = IV 12	Capricorn	IV 13	Capricorn
325	February 14 = VI 20	Aries	VI 21	Aries
	March 3 = VII 7	Taurus	VII 8	Taurus
	March 19 = VII 23	Gemini	VII 24	Gemini?
			Column F	
326	September 9 = I 12	Virgo	I 12	Virgo
	October 1 = II 4	Libra	II 1(!)	Libra
	October 19 = II 22	Scorpio	II 22	Scorpio
	November 6 = III 10	Sagittarius	(III) 10	Sagittarius?
			Column G	
328	August 29 = I 1	Virgo	I 1	Virgo
	September 15 = I 18	Libra	(I) 19	Libra
	October 4 = II 7	Scorpio	II 8	Scorpio
	December 11 = IV 15	Sagittarius	IV 16	Sagittarius
	December 28 = V 2	Capricorn	V 4	Capricorn
329	January 14 = V 19	Aquarius	(V) 20	Aquarius?
			Column H	
331	March 8 = VII 12	Pisces	VII 12	Pisces
	March 24 = VII 28	Aries	VII 28	Aries
	April 9 = VIII 14	Taurus	VIII 14	Taurus
	April 28 = IX 3	Gemini	IX 3	Gemini
	May 25 = IX 30	Taurus	(IX) 30	Taurus
			Column J	
333	March 30 = VIII 4	Taurus	VIII 5	Taurus
	April 12 = VIII 17	Aries	VIII 19	Aries
	May 13 = IX 18	Taurus	IX 19	Taurus
	June 1 = X 7	Gemini	X 8	Gemini
	June 17 = X 23	Cancer	X 24	Cancer

The interval from one column to the next is again generally two years, except for a three year interval between columns Q and R (which are more closely spaced in the papyrus than the columns preceding and on the other side). Between columns T and A, an eight-year interval must be supposed, corresponding to a loss of four columns.

Since at least 32 years of motion of Mercury were covered by the complete almanac, one would expect that the entries for Venus extended well before columns M through P, since an almanac would of course normally cover the same interval of years for all five planets. But this is demonstrably not the case. Although column L is only imperfectly preserved, the surviving numbers cannot be made to fit Venus's recomputed sign entries satisfactorily for any of the three years preceding A.D. 378/379; and similarly column L cannot be made to precede any other sequence of years for which the recomputed almanac closely reproduces columns M through P. Column L must therefore belong to the end of the sign entries for Mars, and this leaves room for only seven or eight years' motion of Venus between Mars and Mercury. Our conclusion is confirmed by the year number 6 preserved in column O, line 5. If this in fact introduces the sixth year of Venus's sign entries, just one year belonging to Venus is lost between the preserved parts of columns L and M. Again, traces of year numbers are visible in line 4 of columns F and G. If my readings are correct, then the first preserved entries for Mercury in column Q belong to Mercury's "year 1"; and this would leave room for just one lost year of Venus following the preserved part of column P, or eight years of Venus in all.

And this result provides the key to the nature of our almanac, since eight years is an accurate recurrence period for Venus, after which it repeats almost exactly the same pattern of motion. Such periods exist for each of the five planets, the shortest reasonably good ones being the so-called "Goal Year" periods first discovered by Mesopotamian astronomers:

Saturn	57 anomalistic periods in 59 years
Jupiter	65 anomalistic periods in 71 years
	or 76 anomalistic periods in 83 years
Mars	37 anomalistic periods in 79 years
	or 22 anomalistic periods in 47 years
Venus	5 anomalistic periods in 8 years
Mercury	145 anomalistic periods in 46 years

It is therefore possible to make a "perpetual" almanac by computing the sign entries for one Goal Year period for each planet. The positions for a given year can be found by establishing where the year in question belongs in each planet's cycle. I think that there can be no doubt that our almanac was of this variety, and that the periods assumed for the planets were Goal Year periods. For the period relations to work, the calendar employed in the almanac would have to be the Alexandrian, since the constant years of 365 days of the old Egyptian calendar are too short to bring about the recurrences: a rare instance where the reformed calendar was more suitable for astronomical purposes.

Since the entries in the almanac were meant to be applicable to a wide range of dates rather than the specific years covered by the other known sign entry almanacs on papyrus, there is little hope of dating the papyrus according to its astronomical contents. Sijpesteijn has endorsed Wessely's palaeographical dating of the papyrus to the fifth or sixth century. I would be surprised if sign entry almanacs were still being used so late, and in any case dating by handwriting is extremely unreliable for a table that consists solely of numerals.

The discovery of a perpetual sign entry almanac reveals an interesting new stage in the evolution of planetary tables, fusing elements derived ultimately from two different kinds of Babylonian text, and pointing ahead to the perpetual almanacs of the Middle Ages. The Greek and Demotic sign entry almanacs for specific dates that we have known up to now are the analogues of a class of cuneiform text referred to (in Sachs's nomenclature) as "Almanacs", which listed the dates and positions of planetary phases and dates of sign entry computed for specific years[4]. Another class of tablets, called "Goal Year Texts", was used to predict planetary phases and stellar passages for a given year by repeating *observations* of these phenomena one Goal Year back in time. The Goal Year Texts have no close counterpart among the papyri, but the period relations on which they were based have already turned up in Greek sources including Ptolemy's *Almagest* IX 3 (where they are ascribed to Hipparchus). It is in our papyrus that the Goal Years seem to have first been applied to the representation of cycles of *computed* planetary positions.

Contemporary with the Greek sign entry almanacs there were other almanacs in use that tabulated planetary longitudes at regular five-day intervals. One published specimen of this kind of table is *P. Heid.* inv. 34, covering at least the years A.D. 345/346 through 348/349[5]. Several other examples are now known, all referring to specific dates in the third and fourth centuries, and all computed using Ptolemy's *Handy Tables*. The mediavel almanacs also present planetary longitudes at five (or ten) day intervals, but organized into Goal Years, just like our papyrus. The oldest mediaeval almanac, that of az-Zarqal (ca. 1075), purports to be an adaptation of one by "Aumanius", i.e. Ammonius[6]; and the association of Ammonius with the Goal Year periods and some sort of tables of planetary longitudes at fixed intervals is confirmed by a chapter on the anomalistic cycles of the planets preserved in the fourteenth-century astrological manuscript *Par. gr.* 2425, ff. 141^{v}—144[7]. I would guess that the first perpetual almanacs were of the sign entry type. From the third century on, as older Babylonian-style arithmetical methods of computing planetary positions were gradually superseded by Ptolemy's works, almanacs at fixed intervals also began to replace the sign entry format, which Ptolemy's tables could not easily be made to generate. In the medieval almanacs, the use of the Goal Year periods is the only vestige of their distant Babylonian ancestry.

2. *P.Vind.* G. 29370 + 29370 B[8].

The original editors identified *P.Vind.* G. 29370 as a fragment of an ephemeris in codex form, giving calendrical and astronomical data for the

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[4] A.J. SACHS, *A Classification of the Babylonian Astronomical Tablets of the Seleucid Period*, Journal of Cuneiform Studies 2 (1948) 271-290.

[5] O. NEUGEBAUER, *An astronomical almanac for the year 348/9 (P.Heid. Inv. No. 34)*, Danske Vid. Selsk., hist.-filol. Medd. 36.4 (1956).

[6] J.M. MILLÀS VALLICROSA, *Estudios sobre Azarquiel* (Madrid/Granada, 1943-1950) 153-234 and 379-400. The almanac has been partially analysed by M. BOUTELLE, *The Almanac of Azarquiel*, Centaurus 12 (1967) 12-19.

[7] An edition by D. PINGREE is forthcoming. The version of the text discussed by O. NEUGEBAUER, *On a Fragment of Heliodorus (?) on Planetary Motion*, Sudhoffs Archiv 42 (1958) 237-244, is more corrupt and lacks the reference to Ammonius.

[8] H. GERSTINGER-O. NEUGEBAUER, *Astronomische Papyri aus Wiener Sammlungen: I. Eine Ephemeride für das Jahr 348 oder 424 n. Chr. in den PER, Pap. Graec. Vindob. 29370*, S.B. AKAD. d. Wiss. Wien, phil.-hist. Kl. 240.2 (1962) 1-25 and pls. I-II.

months March, April, September, and October of a single year. The small fragment *P. Vind.* 29370 B is part of the calendrical columns from another ephemeris. From the leaves belonging to March and September, parts of the six leftmost tabular columns are preserved: (I) days according to the Roman calendar, (II) days of the Roman months counted serially from the first of the month, (III) days of the Alexandrian calendar, (IV) days of the lunar month, beginning with new moon, (V) zodiacal sign occupied by the moon, and (VI) longitude of the moon within its zodiacal sign, in degrees (and minutes?). Along the ruling delimiting the left edge of the table, hooks mark every seventh day. The right sides of the leaves for April and October are preserved, with parts of four tabular columns: (Va) traces of a few zodiacal signs and numerals, (VIa) two sexagesimal places of numerals, (VII) longitude of the moon's ascending node in degrees and minutes, and (VIII) appraisal of the day as "good", "bad", "empty", "ecliptic", or "darkest". Outside the tabular framework on the right edge are what seem to be single-letter or two-letter abbreviations of uncertain meaning, perhaps signifying another method of evaluating the day.

The editors assumed that columns V and VI were the same as the columns I have called Va and VIa, that is, that the only astronomical data in the ephemeris were the longitude of the moon and its node. This economical hypothesis, however, can be shown to be incorrect, notwithstanding the very inadequate remains of these columns. The lunar longitude on March 23 can be read securely as Gemini 1°. Allowing for the loss of the fractional part, this implies that the mean longitude of the moon was between Taurus 23° and Gemini 10°. Thirty-one days later, on April 23, the mean longitude would therefore have been between Cancer 11° and Cancer 29°, and the true moon somewhere between these extremes. But in fact the name of the sign Aries is clearly legible in column Va for April 23, three whole signs away from the moon's position. Hence between columns VI and VII there were columns giving the longitudes of other heavenly bodies, most probably the sun and the five planets in the conventional order Saturn, Jupiter, Mars, Venus, Mercury. We will see presently that Va and VIa do indeed pertain to Venus and Mercury respectively.

In order to establish the year covered by the ephemeris, Neugebauer depended chiefly on the longitudes of the ascending node in column VII, the calendrical equivalences in III and IV, and the lunar longitudes in V and

VI[9]. In selecting possible dates according to the position of the lunar node, however, he applied too strict a criterion, by requiring that the node's tabulated longitude on April 30, 0° 26' in an undetermined zodiacal sign, should correspond to an actual longitude of the node between 0° and 1° as computed according to modern astronomical theory. Two factors contribute to any discrepancy between the node's longitudes as computed according to modern theory and according to ancient tables: error in locating the node which is, after all, invisible with reference to observed positions of the moon, and divergence between where ancient and modern theory situated the zero points of the zodiacal signs. For example, in A.D. 348, the year that Neugebauer ultimately concluded was the date of the ephemeris, modern theory (i.e. the tables of P.V. Neugebauer) gives the longitude of the ascending node as Taurus 0;24° on April 30. Using Ptolemy's *Handy Tables*, on the other hand, one obtains a longitude of Aries 28° 19', two degrees less than modern theory, while the less accurate parameters given in *P. Ryl.* I 27 lead to a longitude of only Aries 29° 21'.

Combining this too strict constraint on the node's longitude with the calendrical information, Neugebauer was left with only the two years A.D. 348 and 424. Subsequently, with the realization that the evaluation "ecliptic" for a day meant that the moon was near one of its nodes on that day, he was able to rule 424 out of consideration[10]. Unfortunately, the actual lunar longitudes for 348, computed by modern theory, differ from the longitudes in the papyrus by an intolerable amount, about 16° on average (which is more than one day's lunar motion). Ancient lunar tables did not err by so much. For example, for March 23, 348, where our ephemeris has a lunar longitude of Gemini 1°, P.V. Neugebauer's tables yield approximately Gemini 17°, the *Handy Tables* yield Gemini 18° 3' (for 6 P.M.), and the scheme of *P.Ryl.* I 27 yields Gemini 22° 3'[11]. Clearly 348 cannot be the right year.

I therefore set out to date the ephemeris afresh, using constraints on

[9] GERSTINGER - NEUGEBAUER, 21-24.

[10] O. NEUGEBAUER, *A History of Ancient Mathematical Astronomy* (Berlin etc., 1975, 1057-1058.

[11] For the reconstruction of the lunar scheme of which *P. Ryl.* I 27 and *PSI* XV 1493 were components, see A. JONES, *The Development and Transmission of 248-Day Schemes for Lunar Motion in Ancient Astronomy*, Archive for History of Exact Sciences 29 (1983) 1-36, esp. 14-23.

accuracy of the lunar and nodal longitudes that are generous enough to allow for plausible variations in ancient predicted positions but not so lax that a surfeit of spurious dates emerges. I selected March 23 as a target date, since the lunar longitude for that day according to the ephemeris is known to be between Gemini 1° and 2°, and the longitude of the ascending node can be restored by extrapolation from preserved parts of column VII as either Aries 2° 25' (give or take a minute) or Libra 2° 25'[12]. Using the computer simulation of the *Handy Tables* I searched for all dates between A.D. 1 and 600 for which the computed longitude of the moon at 6 P.M. was within 10° of Gemini 1° and at the same time the computed longitude of either of the nodes was within 15° of Aries 2°. Only seven years satisfied these requirements: A.D. 33, 52, 470, 489, 508, 554, and 573.

We can now take the lunar calendar dates in column IV into account. March 18 is supposed to be the first day following new moon, so the moon's longitude on this date ought to be slightly higher than the sun's. Again recomputing with the *Handy Tables*, we find that the moon's longitude is nine degrees or more below the sun's in all the selected years except 470, 489, and 508.

Further considerations make it certain that the year of our ephemeris is 489. First, column V contains the abbreviation πρ(οσθετικός), "additive", on or immediately below the lines for March 16 and September 25; and in 489 these were in fact days on which the moon passed its apogee and therefore began increasing its speed. Similarly, the abbreviation ἀφ(αιρετικός), "subtractive", appears on the line for September 11, which in 489 was a day when the moon passed its perigee, and therefore began to slow down. Secondly, in 489 the "hooked" days correspond to Saturday, i.e. the day of Saturn which began the planetary week; and marking Saturdays is the convention followed by two other known papyrus ephemerides, *P. Harris I 60* and *P. Mich.* inv. 1454[13]. Thirdly, the positions of the planets Venus and Mercury turn out to be in agreement with the traces of columns Va and

[12] That these are the only possible zodiacal signs for the node can be deduced from the days characterized as "ecliptic" in column VIII.

[13] A. JONES, *An Astronomical Ephemeris for A.D. 140: P. Harris I 60*, ZPE 100 (1994) 59-63. H.D. CURTIS and F.E. ROBBINS, *An Ephemeris of 467 A.D.*, Publications of the Observatory of the University of Michigan 6.9 (1935) 77-100.

VIa, and in particular Venus actually entered Aries on or near April 23, as indicated in the papyrus.

But the most conclusive argument for the year 489 is also a point of independent interest: the agreement between the contents of the papyrus and recomputation using the *Handy Tables* is so exact that the ephemeris must itself have been computed from Ptolemy's tables. Assuming 6 P.M. (i.e. "sunset epoch") as the time of day for which longitudes were computed, I found nodal longitudes consistently within two minutes of those in the papyrus, and all secure readings in the lunar columns V and VI were reproduced except for the entry into Aquarius on September 21 instead of September 20 (probably an isolated error). The longitudes of Venus and Mercury, where legible, are within a few minutes of the *Handy Tables* values; the larger discrepancies may be because some longitudes were found by interpolation between a few directly computed positions. And days characterized as "ecliptic" are precisely those on which the *Handy Tables* put the moon in the same sign as the node.

The small fragment *P. Vind.* 29370b, which evidently belongs to another ephemeris, contains only a few lines from three calendrical columns and the column giving the moon's zodiacal sign. Nevertheless this information is enough to date it securely. The first calendar is obviously the Roman, and *a priori* the other two are most likely to be the Alexandrian and lunar calendars respectively. As Neugebauer shows, the equivalence of a Roman date X a. Kal. and an Alexandrian date 25 is possible if the day is (i) February 20 of a Julian leap year, (ii) September 22 of any year that is *not* an Alexandrian leap year (i.e. not the year before a Julian leap year), (iii) October 23 of an Alexandrian leap year, or (iv) November 22 of an Alexandrian leap year[14].

We also know that on this day the moon had just entered the sign Leo. Since according to the third column the day is the 24th since new moon, the moon's (and hence the sun's) longitude at the next new moon, six or seven days later, would be in or near the sign Pisces. This definitely rules out possibility (i). Finally, we have a hook next to this same line, which, as we have seen, marks the day as a Saturday.

Using the *Handy Tables* simulation, I determined all years between A.D. 200 and 600 for which the dates of possibilities (ii) through (iv) yielded Sa-

[14] Gerstinger & Neugebauer, 24.

turdays with lunar longitudes between Leo 0° and Leo 16°. Only four dates remained: 251 November 22, 335 November 22, 417 September 22, and 471 October 23. Taking the lunar calendar into account eliminates all candidates except 471 October 23, which was the 24th day since new moon (the other dates are all more than two days off). The so-called "recto" of *P. Vind.* 29370b thus covered October of A.D. 471, and the other side probably covered September, with the few extant traces belonging to the rightmost columns.

The revised date for *P. Vind.* G. 29370 brings it into much closer proximity with the other published ephemeris from late antiquity, *P. Mich.* inv. 1454, which covers September and October, A.D. 467. As it turns out, both were computed using the *Handy Tables*[15], both give daily positions of the planets and (probably) the sun, as well as the moon; and both belonged to codices. It seems certain that these are both specimens of what was a fairly standard format of table, intended primarily for catarchic astrology (the determination of auspicious and inauspicious days) but also probably useful for casting horoscopes.

Toronto *Alexander Jones*

[15] This was demonstrated for P. MICH. inv. 1454 by J.J. BURCKHARDT, *Zwei griechische Ephemeriden*, Osiris 13 (1958) 79-92.

TRE PAPIRI TOLEMAICI DELLA BIBLIOTECA APOSTOLICA VATICANA*

1. Dichiarazione di *naukleros* (*P. Vat. Gr.* 66)

Arsinoites: Philagris cm 8,8 × 28,7 26.12.219 a.C.

Su una striscia rettangolare di papiro, recuperata da *cartonnage*, si conserva lungo le fibre una dichiarazione di *naukleros*, quasi completa (margine superiore cm 3, inferiore cm 2, *kollesis* a cm 1 dal margine destro): il *verso* non conserva tracce di scrittura.

Per quanto lo stato di conservazione della superfice del papiro, a seguito delle operazioni di recupero del *cartonnage* non sia ottimo (la scrittura è in molti punti svanita), la formularità e l'ampia attestazione di questo tipo di dichiarazioni permettono una lettura ed interpretazione piuttosto sicure.

Theodotos, *naukleros* al servizio di Agathokleia, dichiara di aver imbarcato per il trasporto ad un luogo di sbarco presso Φιλαγρίς, (εἰς τὸν περὶ Φιλαγρίδα ὅρμον, rr. 9-11), 2772 artabe di granaglie (orzo o sim.).

La struttura della dichiarazione segue lo schema tradizionale di questo tipo di documenti, le cui attestazioni si sono in questi ultimi anni sensibilmente accresciute: cfr. i testi in *P. Erasm.* II [Stud. Amst. 32]; i papiri Austin pubblicati da D.G. Herring in *ZPE* 76 (1989), pp. 27-37; le dieci ricevute granarie pubblicate da W. Clarysse-H. Hauben, in *ZPE* 89 (1991), pp. 47-68; l'edizione di *PUG* III 114 e 115 (nell'introduzione e nel commento si cfr. la ricca bibliografia sull'argomento).

Ma l'interesse maggiore della nostra dichiarazione risiede nella presenza

* Della stessa provenienza il *P. Vat. Gr.* 65, pubblicato in *Tyche* 5(1990), pp. 101-4. - Risolutivi suggerimenti ci sono venuti da G. Messeri Savorelli.