Gaia Fanelli – Alexander Jones

A Late First Century BC Greek Astronomical Almanac: *P.Petrie Mus. astr.*

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Introduction

The fragments of an astronomical table edited here belong to the Petrie Museum, University College London, though they were not catalogued with the museum's collection in 2005 and lack an inventory number.[1] They are mounted, rather haphazardly, in a glass frame together with a postal envelope addressed to "Prof. W. M. F. Petrie. Lahun, Via Fayum" from the Cairo provisioners Jules & Henri Fleurent, with several Egyptian post office marks dated 23–24 March 1920. A handwritten annotation "Kalendar" on the envelope's front confirms that Petrie had reused it to store the papyrus fragments.[2] Petrie must have acquired the papyrus, likely by purchase, during his 1919–1920 season at Lahun. Nothing can be deduced about the papyrus's provenance from its contents.

The manuscript was in roll format, and the table is written along the fibers within a tabular frame ruled in black; horizontal rules separate each row at intervals of about 0.8 cm, and double vertical rules separate the columns at intervals of about 6 cm. The backs are blank. After joins, there are twenty-one fragments (Figure 1). Some preserve parts of the upper margin, to a maximum breadth of about 2.5 cm, and one preserves part of the lower margin, to approximately the same breadth. No fragment appears to preserve either the left or right extremities of the table. The text is in an experienced, somewhat irregular informal rounded hand with some ligatures, and with a tendency to more formal and separated letters in the header rows identifying regnal years and planets; a dating to the latter part of the first century BC or the first century AD is plausible from the paleography, and will be confirmed below from the table's contents. A peculiarity is the presence of largish oval spots of pink (not red) pigment preceding the text of the header rows, represented in the edition by small dots.[3]

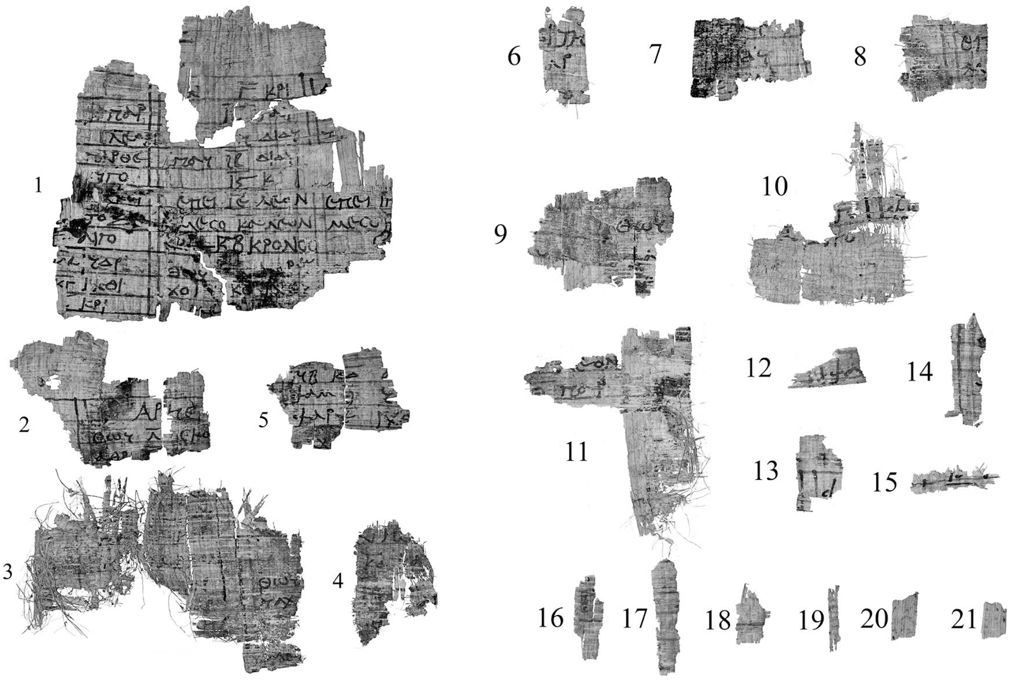

Fig. 1. *P.Petrie Mus. astr.*

[1] A preliminary study of this papyrus was made by Gaia Fanelli as part of the London Summer School of Papyrology organized by Cornelia Römer in 2003; our subsequent collaboration on it was long impeded by difficulties in organizing the fragments together with professional distractions. We wish to thank the Petrie Museum, Cornelia Römer, and Nikolaos Gonis for access to the papyrus and permission to publish it.

[2] The idiosyncratic spelling "kalendar" was characteristic of Petrie; see for example his contributions to Knobel *et al*. 1911.

[3] Cf. the use of pink ink in *P.Oxy. astr.* 4175, c. 24 BC, for the abbreviations of Roman calendar days.

The table belongs to the broad class known as “almanacs”, which list precomputed zodiacal positions of the five planets known in antiquity (Saturn, Jupiter, Mars, Venus and Mercury) at uniform or variable intervals over a span of several years. The primary use of almanacs is presumed to have been to provide the planetary data for horoscopic astrology. The specific type in question is the “sign-entry almanac”, the characteristics of which will be discussed in the astronomical commentary below.

Edition

We offer translations only for the fragments (1–5) whose planets and years are identifiable from the preserved contents, as shown in the commentary. The notation *x* stands for an unknown numeric digit.

Fragment 1: 12.8 × 11.8 cm, top margin 2.5 cm, broken on remaining sides.

(in top mg above col. ii)]Ζ̣?

i	ii	iii
• Ἀφροδίτη] *vac.*	[Π]αχ̣(ὼν) *vac.* γ̅ Κρι(ῷ)	Ἀ[θὺρ *xx* Αἰγό(κερῳ)
Θὼθ] κ̣̅ Παρ(θένῳ)	Π̣[αχ(ὼν)] ι̅ϛ̅ Ταύ(ρῳ)	Χ̣[οι(ὰκ) *xx* Ὑδρ(ο)χ(ό)ῳ
] Λέον(τι)	[Παχ(ὼν)] κ̣̅η̅ Διδύ(μοις)	Τ̣ῦ[βι *xx* Ἰχθῦ(σι)
] Παρθέ(νῳ)	Παῦ(νι) ι̅β̅ Διδύ(μοις)	[Μεχ(εὶρ) *xx* Κρι(ῷ)
Ἀ[θὺρ *xx*] Ζ̣υγο(ῦ)	*vac.* ι̅ϛ̅ Κ[αρ(κίνῳ)]	[Παῦ(νι) *xx* Ταύ(ρῳ)
Χοι(ὰκ) ι̅]γ̣̅ Σκορ(πίῳ)	Ἐπεὶ(φ) ι̅ε̅ Λέον(τι)	Ἐπεὶ(φ) ι̅η̅ [Διδύ(μοις)
Τῦβι *xx*] Τοξ(ότῃ)	Μεσο(ρὴ) κ̅α̅ Λέον(τι)	Μεσο(ρὴ) κ̣̅[*x* Καρ(κίνῳ)
Μεχ(εὶρ)] γ̣̅ Αἰγό(κερῳ)	• ⟦ ̣ ̣⟧ (ἔ̣τ̣ο̣υ̣ς̣) κβ Κρόνος	• Ἑ̣ρ̣[μῆς
Μεχ(εὶρ)] κ̅ε̅ Ὑδρ(οχόῳ)	Θωὺ(θ) α̣̅ Ὑδρ(ο)χ̣(ό)ῳ	Θ̣ῴ[θ
Φαμε(νὼθ)] κ̅γ̅ Ἰχθῖ(σι)	Χοι(ὰκ) κ̅θ̅ Ἰχθῦ(σι)	[
Φαρ(μοῦθι) *x*]̣̅ Κρι(ῷ)	[Φα]με ̣ ̣ ι̅η̣̅ Ἰ̣χ̣[θῦ(σι)]	[

— — — — — — — —

i 6 *l.* Ζυγῷ | 11 *l.* Ἰχθῦσι | ii 10 *l.* Θὼθ | 12 *scil.* Φαμενὼθ

(in top mg above col. ii)]7?

i	ii	iii
• Venus] *vac.*	[P]achon *vac.* 3 Aries	Ha[thyr *xx* Capricorn
Thoth] 20? Virgo	P[achon] 16 Taurus	Ch[oeac *xx* Aquarius
] Leo	[Pachon] 28 Gemini	Ty[bi *xx* Pisces
] Virgo	Payni 12 Gemini	[Mecheir *xx* Aries
Ha[thyr *xx*] Libra	*vac.* 16 C[ancer]	[Payni *xx* Taurus
Choeac 1]3 Scorpio	Epeiph 15 Leo	Epeiph 18 [Gemini
Tybi *xx*] Sagittarius	Mesore 21 Leo	Mesore 2[*x* Cancer
Mecheir] 3 Capricorn	• ⟦…⟧ Year 22 Saturn	• Mer[cury
Mecheir] 25 Aquarius	Thoth 1 Aquarius	Tho[th
Phamenoth] 23 Pisces	Choeac 29 Pisces	[
Pharmouthi *x*]*x* Aries	[Pha]menoth 18 Pis[ces]	[

— — — — — — — —

Fragment 2: 7.5 × 6.6 cm, top margin 2.5 cm, broken on remaining sides.

vac	• Ἄρης
]	Θωὺ(θ) λ̅ Σκο[ρ(πίῳ)
]	Ἀθ(ὺ)ρ ς̅ Σ̣κ̣[ορ(πίῳ)
	] *vac*. [*x̅x̅* Τοξ(ότῃ)
	Χ]οι(ὰκ) [*xx* Αἰγό(κερῳ)

— — — — — —

2 *l.* Θὼθ

vac	• Mars
]	Thoth 30 Sco[rpio
]	Hathyr 6? Sc[orpio
	] [*xx* Sagittarius
	Ch]oeac [*xx* Capricorn

— — — — — —

Fragment 3: 10.4 × 7.6 cm, broken on all sides. The ruling below line 9 seems to be the bottom one of the table.

	i	ii
	— — — — — —	
	] ̣[	
]	[Φαμε(νὼθ)] κ̣ς̣̅ Ταύ̣(ρῳ)	[
]	Φαρ(μοῦθι) κα̅ Διδύ(μοις)	[
̣[ ]	Παχ̣(ὼν) ι̣ς̣̅ Καρ(κίνῳ)	. . .[
̣[ ]	Παῦ̣(νι) ια̅ Λέον(τι)	• [Ἄρης
κ̅[ ]	] Παρ(θένῳ)	Θωὺ(θ) [
̣̅[ ]	Π]αρ(θένῳ)	Παχ(ὼν) [
]	• Ἑρ]μ̣ής	. . . [
	]	*vac.?*
	]	Μεσ̣[ο(ρὴ)

— — — — — —

ii 6 *l.* Θὼθ

— — — — — —

	]. . .[	
]	[Phamenoth] 26? Taurus	[
]	Pharmouthi 21 Gemini	[
. . .[ ]	Pachon 16? Cancer	. . .[
. . .[ ]	Payni 11 Leo	• [Mars
2[*x*]	] Virgo	Thoth [
x[ ]	V]irgo	Pachon [

]	• Mer]cury	…[
	]	*vac.?*
	]	Mes[ore

— — — — — —

Fragment 4: 3.2 × 4.7 cm, broken on all sides.

— — — — — —

•	] Ἄ̣ρης [
	] κ̅δ̅ Καρ̣(κίνῳ) [
	] κ̅ ̣ Λέ[ον(τι)
	] ι̣̅γ̅ Π̣αρ(θένῳ) [
	] ι̣̅θ̅ [
	] ̣[

— — — — — —

— — — — — —

•	] Mars [
	] 24 Cancer[
	] 2*x* Le[o
	] 13? Virgo [
	] 19 [
	]…[

— — — — — —

Fragment 5: 7.6 × 5.2 cm, broken on all sides.

— — — — — —

	] ̣[
]	Τῦβ(ι) κ̅δ̅ Α[ἰγό(κερῳ)
]	Φαμ(ενὼθ) θ̅ Ὑδ̣[ρ(ο)χ(ό)ῳ
]	Φαρ(μοῦθι) ε̅ Ἰχθ[ῦσι
]	Παχ(ὼν) [*xx*

— — — — — —

— — — — — —

	]…[
]	Tybi 24 C[apricorn
]	Phamenoth 9 Aq[uarius
]	Pharmouthi 5 Pis[ces
]	Pachon [*xx*

— — — — — —

Fragment 6: 1.5 × 2.9 cm, broken on all sides.

— — — — —

	Ἀφρο]δίτη [
	Π]αρ(θένῳ) [
3	Ζυ]γο(ῦ) ̣[

— — — — —

3 *l.* Ζυγῷ

Fragment 7: 3.2 × 2.4 cm, broken on all sides.

— — — — — —

	] Ταύ(ρῳ)	
	] ̣̄ Διδύ(μοις)	
3	] κ̄ᾱ Κα̣ρ̣(κίνῳ)	

— — — — — —

Fragment 8: 2.7 × 2.5 cm, broken on all sides.

	i	ii
	— — —	— — — —
	] Σ̣κο̣(ρπίῳ)	Ἐπ[εὶ(φ) *xx*
2	] Τ̣οξ̣(ότῃ)	Μ[εσο(ρὴ) *xx*

— — — — — —

Fragment 9: 4.5 × 3.6 cm, broken on all sides.

— — — — — —

	]	*vac.* [
	] ̣	Θωὺ(θ) [*xx*
	] ̣	Φα[ῶ(φι) [*xx*
4	]	Ἀ̣θ[ὺρ *xx*

— — — — — —

2 *l.* Θὼθ

Fragment 10: 5.2 × 5.3 cm, 2.5 cm bottom margin, broken on remaining sides. Line 2 is written below the bottom ruling of the tabular frame.

	i	ii
	— — —	— — —
		traces
	Σκορ]π(ίῳ)	Φα̣[
2	]α Ζυγο(ῦ)	[

2 *l.* Ζυγῷ

Fragment 11: 5.1 × 6.4 cm, broken on all sides. There are traces of three or four horizontal rulings below the last transcribed line.

	i		ii
	— — — — — —		
			] ̣ [
	̣̅] Λέον(τι)	[	] ̣ ̣ [
3	] θ̅ Παρ(θένῳ)	[	] ̣ [
	— — — — — —		

Fragment 12: 2.4 × 1.3 cm, broken on all sides.

— — —

1	]	Φα[

— — —

Fragment 13: 1.4 × 2.1 cm, 1.0 cm top margin preserved, broken on the remaining sides.

1	]	Φ[

— — —

Fragment 14: 1.3 × 3.4 cm, broken on all sides.

— — —

	]	Ἀ[θὺρ *xx*
	]	[
	]	Ṭ[ῦβι *xx*
4	]	[

— — —

Fragment 15: 2.7 × 0.8 cm, broken on all sides.

— — —

] ̣ ι̣̅α̣̅ Ạ[ἰγό(κερῳ)

2] [*x̅x̅*] [

— — —

Fragments 16 (1.1 × 2.6 cm), 17 (0.9 × 3.5 cm) and 18 (1.8 × 1.8 cm) have only horizontal rulings, with very doubtful specks of ink along 16’s top edge and 17’s right edge. Fragments 19 (0.3 × 1.9 cm), 20 (0.7 × 1.6 cm) and 21 (0.8 × 1.1 cm) are blank. All these fragments are broken on all sides.

Astronomical commentary

The broad structure of a sign-entry almanac remained highly uniform through the more than three centuries for which this type of table is attested.[4] At the largest scale, the almanac consisted of a sequence of top-level sections pertaining to consecutive calendar years in either the old, unintercalated Egyptian calendar – often preferred as a basis for astronomical chronology because of its constant year lengths – or the reformed civil calendar. The years were specified, normally by regnal years of the current emperor, in a header row. This was followed by five subsections pertaining to each of the five planets, always in the order Saturn, Jupiter, Mars, Venus, Mercury. In some almanacs each subsection's planet was named in a subheader row, whereas in others it was left to the user to identify the relevant planet by its position in the standardized sequence.

Aside from the subheader, if present, each planetary subsection comprised rows of data in the format month, day, zodiacal sign (or in some almanacs just day, zodiacal sign if the month of the preceding row was to be understood as continuing), in chronological order. The normal meaning of one of these date-sign combinations was that the planet in question was computed to have entered the stated zodiacal sign on the stated date; in other words, if it was moving direct (eastwards) through the zodiac, the planet was at 0° of the stated zodiacal sign at some time during that day, but if it was moving retrograde (westwards), it was at 30° in the stated sign, or equivalently, 0° in the next sign eastwards. In addition to these dates of sign-entry, a planetary subsection could also begin with a row for the first day of the year (Thoth 1), stating the zodiacal sign occupied by the planet at the year's beginning, and there might also be rows giving dates and associated zodiacal signs corresponding to other stages in the planet's motion besides its sign-entries, for example dates of first visibility.

The ancient user of a sign-entry almanac would normally have wanted to know just one thing, namely which zodiacal sign a planet occupied on a given date. If the given date appeared in the subsection belonging to the appropriate year and planet, the associated zodiacal sign was the answer; otherwise one took the zodiacal sign corresponding to whichever listed date was the latest one preceding the given date. In other words, the meaning of any row for practical purposes was that the planet was *somewhere* in the stated zodiacal sign on the listed date and remained in that sign *at least* until the date in the following row, or in the case of a subsection's last row *at least* until the end of the year. The reason for including synodic-cycle events along with the dates of sign-entry in some almanacs is not clear. The almanacs that have such events do not generally identify what the events are. It seems likely that they are artifacts of the methods employed to compute daily longitudes of the planets, which involved first finding the dates and longitudes of synodic events and then extrapolating the longitudes on subsequent days through arithmetical sequences.[5]

For the purposes of our astronomical analysis, however, the almanac yields more information, which in the first instance can be helpful for identifying the planets and years to which individual planets pertain. If a row containing a zodiacal sign immediately follows a row containing the *preceding* zodiacal sign in the conventional west-to-east order, we know that the planet was assumed to be moving in direct (eastward) motion and was within a day's daily motion – i.e. at most about 2° for the fastest planet, Mercury – of the beginning (0°) of the sign. If a row follows a row containing the *following* zodiacal sign, we know that the planet was assumed to be moving retrograde (westward) and was within a day's motion of the end (30°) of the sign. If a row follows a row containing the *same* sign, we know that the planet was computed to be within 15° of the middle (15°) of the sign, and also that the date corresponds to some significant stage of the planet's synodic cycle, that is, a first or last visibility in the morning or evening, a station, or an opposition.

In the present papyrus, Fragment 1 col. ii line 9 preserves a row that serves simultaneously as header for a year (regnal year 22) and subheader for the data for Saturn. This is followed by three surviving rows

[4] For a description of the format, variations in its details, and inventory of examples see Jones 1999a, 1.42–45 or Jones 1999b, 324–326. P.Stras. inv. 1097, listed there (on Neugebauer's authority) as a sign-entry almanac, is a different type of astronomical table; see Jones 2018. Additional sign-entry almanacs published since 1999: Jones 2001 (P.Fay. ined. s.n., i and ii), Jones–Perale 2011 (PSI inv. D 93), and Jones 2012 (P.Yale CtYBR inv. 3775).

[5] For further discussion of these methods see Jones 1999a, 1.19–33.

indicating that Saturn was within Aquarius at the beginning of the year, that it had crossed in direct motion into Pisces on Choeac 29, and that a synodic-cycle event took place on Phamenoth 18th while Saturn was still in Pisces. Within the most generous credible chronological range compatible with the paleographical dating, the only reigns long enough to have a year 22 were those of Cleopatra VII (year 22 = 31/30 BC), Augustus (year 22 = 9/8 BC), and Tiberius (year 22 = AD 35/36). In the first and third of these candidate years, Saturn was respectively in Gemini and in Leo and Virgo, but in Augustus 22 it began the year in Aquarius and ended it in Pisces. Below we give sidereal longitudes of Saturn on Thoth 1, Choeac 29, and Phamenoth 18 in each of these years according to both the old and the reformed Egyptian calendars, computed by modern theory:[6]

Date	*Tropical*	*Sidereal*
Thoth 1 (old calendar) = 9 BC August 25	Aquarius 22° 8'	Aquarius 28° 1'
Thoth 1 (reformed) = 9 BC August 29	Aquarius 21° 50'	Aquarius 27° 43'
Choeac 29 (old calendar) = 9 BC December 21	Aquarius 22° 2'	Aquarius 27° 55'
Choeac 29 (reformed) = 9 BC December 25	Aquarius 22° 25'	Aquarius 28° 18'
Phamenoth 18 (old calendar) = 8 BC March 10	Pisces 1° 12'	Pisces 7° 5'
Phamenoth 18 (reformed) = 8 BC March 14	Pisces 1° 42'	Pisces 7° 35'

Obviously, then, we are dealing with dates in Augustus 22; and with a divergence of just four days between the two versions of the calendar in that year, there is no way to tell which one the almanac was based on. The longitudes of Saturn according to whatever tables were employed by the composer of the almanac must have been roughly 8° higher than correct tropical longitudes, confirming that the longitudinal frame of reference was, as usual for such tables, sidereal.[7] The phenomenon recorded in line 12, coming about twenty days after conjunction (on February 19), must have been Saturn's first morning appearance; according to

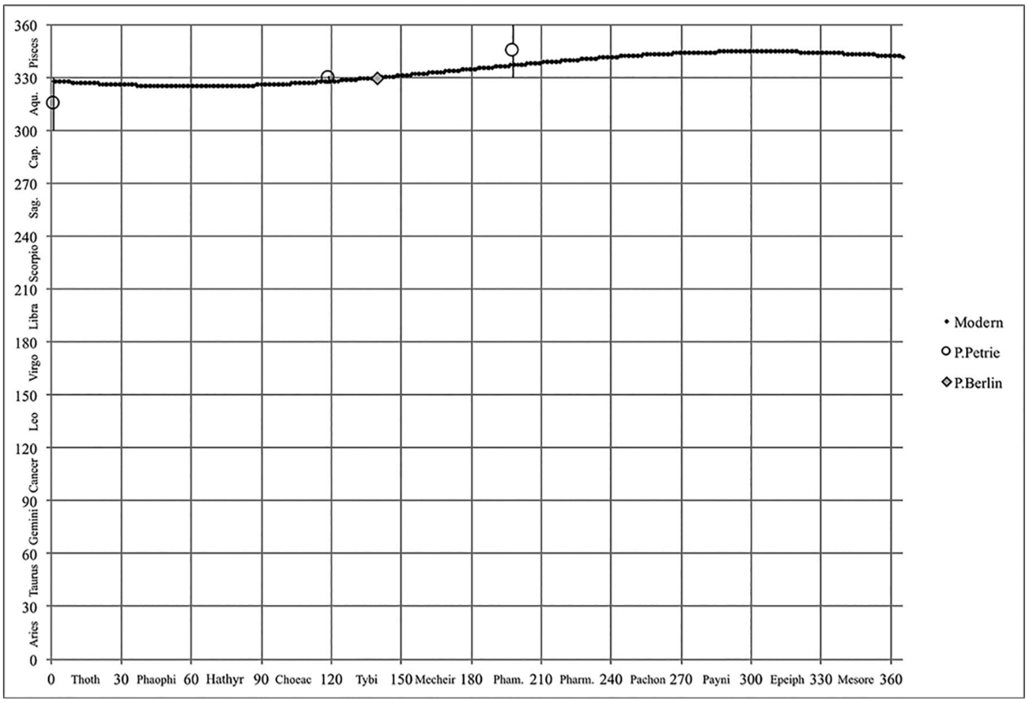

Fig. 2. Longitudinal motion of Saturn in Augustus 22 (9/8 BC) according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279. In Figs. 2–10, the horizontal axis represents the date according to the unreformed Egyptian calendar, and the vertical axis represents sidereal longitude.

6 Tropical longitudes are computed for 0h UT by the JPL Horizons ephemeris (https://ssd.jpl.nasa.gov/horizons.cgi). Sidereal longitudes are greater by 6° 15' – x/60 where x is the year in the Era Augustus, following the approximate formula for obtaining a typical sidereal norm for Roman-period astronomy given in Jones 1999a, 1.343.

7 Neugebauer 1975, 2.786; Jones 1999a, 1.49.

modern-theory estimation, this event would have taken place on March 19.[8] Figure 2 shows graphically the correspondence of the papyrus's dates and longitudes (small circles) with the sidereal motion of Saturn as computed by modern theory through the old calendar year (line).

Col. ii lines 2–8 must pertain to Mercury during the last months of Augustus 21 (10/9 BC), completing a subsection for that planet that would have begun in col. i. Lines 3–4 and 6–7 record sign-entries in direct motion, while lines 5 and 8 represent synodic events; the status of line 2 is not evident since we cannot compare it with the preceding row of the table. The following is a comparison of the data in these rows with modern theory sidereal longitudes of Mercury for the equivalent dates in 9 BC according to the two versions of the calendar (cf. Figure 3):

Papyrus	*Old calendar*	*Reformed calendar*
Pachon 3 Aries	April 24 Aries 12° 3'	April 28 Aries 17° 4'
Pachon 16 Taurus 0°	May 7 Taurus 0° 55'	May 11 Taurus 8° 9'
Pachon 28 Gemini 0°	May 19 Taurus 24° 23'	May 23 Gemini 3° 4'
Payni 12 Gemini	June 2 Gemini 24° 23'	June 6 Cancer 2° 14'
Payni 16 Cancer 0°	June 6 Cancer 2° 14'	June 10 Cancer 9° 34'
Epeiph 15 Leo 0°	July 5 Leo 12° 42'	July 9 Leo 15° 26'
Mesore 21 Leo	August 10 Leo 4° 20'	August 14 Leo 6° 29'

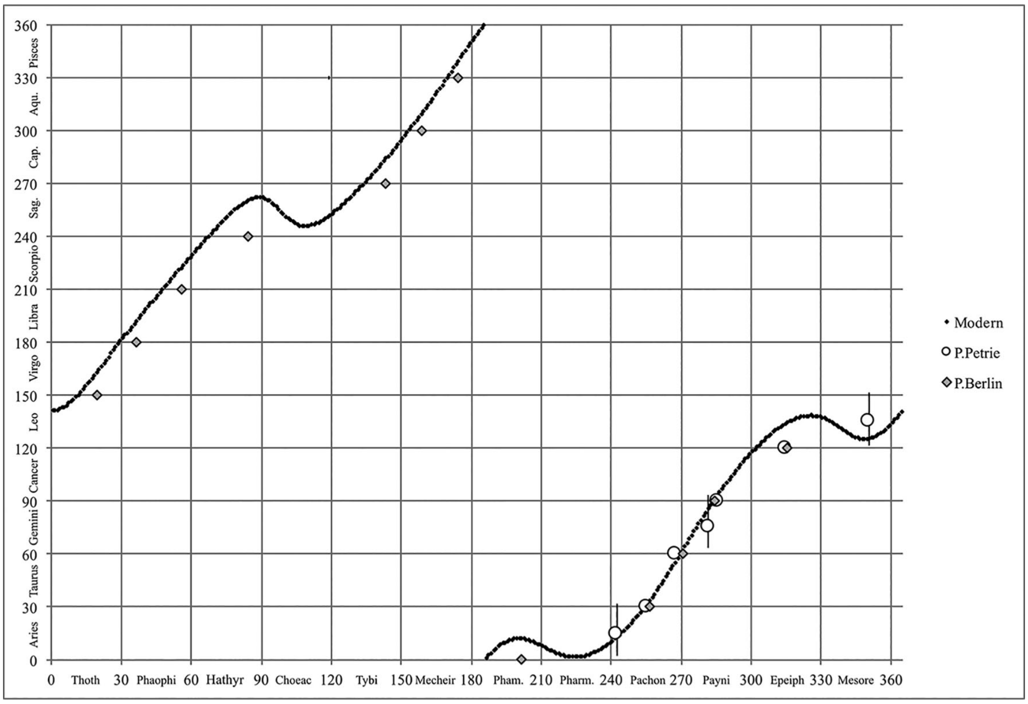

Fig. 3. Longitudinal motion of Mercury in Augustus 21 (10/9 BC) according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

According to modern-theory estimation, Mercury made its first evening appearance on June 2 and its first morning appearance on August 8, so these must be the events recorded in lines 5 and 8. The planet probably did not reach a sufficient elongation from the Sun to be visible in the morning during the interval during Pachon and Payni when it was rising ahead of the Sun, but since the date in line 2 is about a month after inferior conjunction, close to greatest morning elongation, and is unlikely to be meant for a date of sign-entry, it probably is a nominal first morning appearance necessary for computational continuity.[9]

[8] For such events I have used the tables computed by modern theory for Alexandria in Carman–Duke 2019, e.g. table saturn1650v for Saturn.

[9] For such nominal dates of first appearances of Mercury generated by Babylonian methods of computing Mercury's synodic phenomena, see Neugebauer 1975, 1.403–404. These methods are now known to have been widely used in Roman Egypt;

The agreement of the data in the papyrus with modern theory is satisfactory, especially on the assumption of the old calendar, with larger discrepancies around the interval of slower and retrograde motion in the last months of the year, the stages of Mercury's synodic cycle in which ancient theories tended to be least accurate.

The eleven preserved lines of col. i are missing the month names and many of the day numbers, but evidently pertain to a single planet, with its header row (lost) in line 2. The planet was in Virgo in line 3, thereafter reentered Leo in retrograde motion in line 4, and during the remainder of the year progressed at least as far as Aries. The planet in question cannot have been Saturn or Jupiter, neither of which can advance through parts of more than one or two zodiacal signs in a year. Moreover, Mars could not have moved retrograde through Virgo and Leo at the beginning of the calendar year, because the planet would have been close to conjunction with the Sun, whereas Mars's retrogradations occur around its opposition. This leaves Venus and Mercury as possible candidates.

A complete set of sign-entries for the five planets for most single years amounts to around thirty-five to forty-five tabular rows; with header rows and intermittent synodic events, a year would normally have required about forty-five to fifty-five rows.[10] Since the row height in the papyrus is about 0.8 cm, while the available height of the roll was probably not much over 30 cm, we can estimate that a typical column of the almanac likely contained less than a year's worth of data, and certainly not closer to two years' worth. This would make the preserved part of col. i belong to Augustus 20 or 21. Within these constraints, the only identifications that could plausibly yield the required retrogradation from Virgo into Leo at the beginning of the year are Mercury in Augustus 20 (11/10 BC) and Venus in Augustus 21 (10/9 BC).

The fit for Mercury in Augustus 20 is poor. According to modern theory, Mercury had a retrogradation in the first months of the year, but remained in Virgo throughout this stage. There is a still more serious difficulty with i 10–11, according to which the planet travelled direct the 30° from Aquarius 0° to Pisces 0° in 28 days (or 28 days plus one or more complete Egyptian months). In Augustus 20, Mercury was in its interval of most rapid direct motion while passing through Virgo, requiring just 16 days to traverse the sign.

On the other hand, we find a convincing fit for Venus in Augustus 21 (Figure 4). Venus moved retrograde into Leo in sidereal longitude already around August 29, 10 BC (Augustus 21, Thoth 4 old calendar), but it would require only a small positive difference between sidereal and tropical longitudes to reduce its presence in Leo to a few days beginning late in Thoth. The event of i 2, with date restored as Thoth 20 (September 14), practically coincides with the planet's morning station as computed by modern theory (September 13), but cannot have been meant for that event since morning station marks the *end* of Venus's retrogradation, so it is probably a not-terribly-accurate first morning appearance, estimated by modern theory for August 29. According to modern theory, Venus traversed tropical Aquarius in 25 days, from February 21 to March 17, 9 BC (old calendar Mecheir 30 to Phamenoth 25), in good agreement with the dates in i 10–11. Because Venus's rate of motion stays close to constant through much of its intervals of direct motion, we can conjecturally restore a sequence of approximate dates for i 7–12 on the assumption that Venus travels 30° in 25 days:

i 7	Choeac 13 Scorpio
i 8	Tybi 8 Sagittarius
i 9	Mecheir 3 Capricorn
i 10	Mecheir 28 Aquarius
i 11	Phamenoth 23 Pisces
i 12	Pharmouthi 18 Aries

see Jones 1999a, 1.114–115 (with the commentaries to *P.Oxy. astr.* 4152–4156c), Jones 2007 (PSI inv. 1), and Ossendrijver–Winkler 2018 (*O.Ashm. Dem.* 483 and 525+). Ptolemy, *Almagest* 13.8 discusses Mercury's "missing phases" from the point of view of his model for planetary visibility.

[10] The possible numbers of sign-entry rows for the individual planets for a single year are: Saturn 1–4, Jupiter 1–4, Mars 4–10, Venus 11–16, and Mercury 13–19, in each case assuming an initial row for Thoth 1. Hence years with as few as 30 or as many as 53 sign-entry rows are theoretically possible, but such extremes rarely occur.

These reconstructed dates are consistent with all traces in the papyrus except for the discrepancy of three days in i 10, which I suspect is the result of a scribal error.

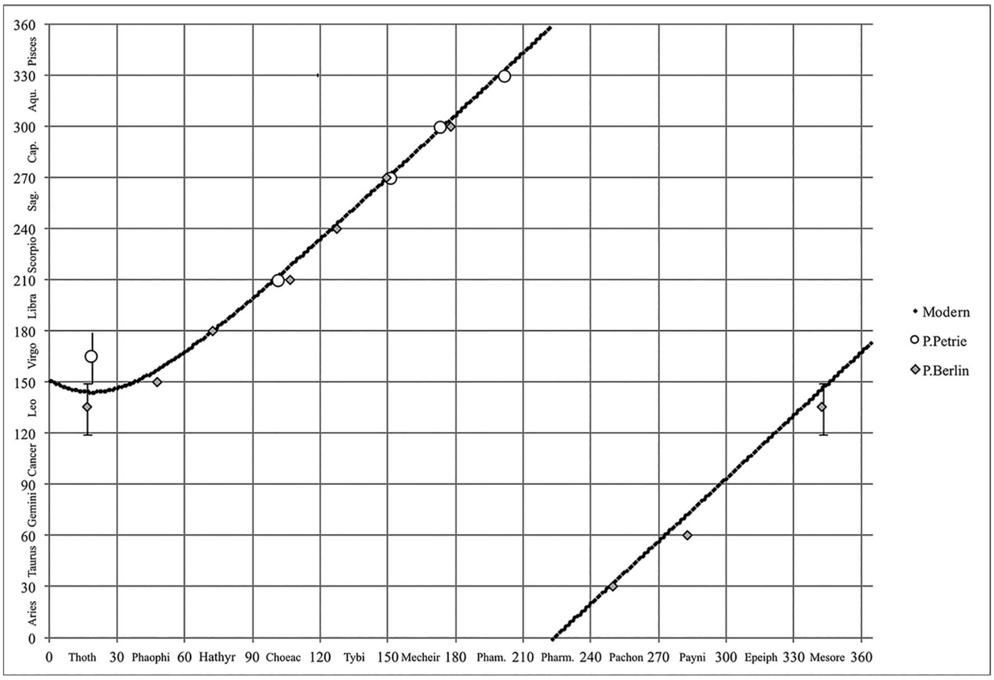

Fig. 4. Longitudinal motion of Venus in Augustus 21 (10/9 BC)
according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

Venus would have completed the year with five further sign-entries in direct motion. How many sign-entries of Mercury from the first part of Augustus 21 have been lost before the beginning of col. ii is less certain because this depends on whether its retrogradations took place entirely within single signs or involved multiple boundary crossings, but the minimum is seven, with nine or eleven more probable. Allowing for a subheader row for Mercury and some additional date-sign statements for non-sign-entry events, we can estimate that the complete table had around 30 rows.

The remains of column iii must therefore belong to Venus (iii 2–8) and Mercury (iii 9–10) in Augustus 22. The fact that Venus has experienced at most two sign-entries in an interval of roughly six months between some date in Tybi and Epeiph 18 shows that a retrogradation must fall within this time, and one, moreover, such that the planet remains within a single zodiacal sign. This condition is fulfilled for Augustus 22 (Figure 5).

Fragment 2 has a subheader for the planet Mars in the top row of the table, followed by a sign-entry into Scorpio on Thoth 30, an event on Hathyr 6, another later in the same month, and a fourth in Choeac. The event on Hathyr 6, according to the remaining traces of the sign name which are consistent with Scorpio but not with Sagittarius or Libra, was not a sign-entry. The only year close to Augustus 21–22 that this fragment could belong to is Augustus 20 (Figure 6). In that year, Mars's tropical longitude on old calendar Thoth 30 (September 24) was Libra 25° 44', and the planet was in direct motion, approaching conjunction on January 12. Its elongation from the Sun on old calendar Hathyr 6 (October 30) was 17° 43', identifying the event as last evening visibility, and the events in the next two rows as sign-entries in direct motion into Sagittarius and Capricorn. The column to which Fragment 2 belonged would have been two columns to the left of Fragment 1 col. i.

The planet in Fragment 3 col. i, 2–7 must be Venus since line 8 is the header for Mercury. The preserved data, in particular the advance from the beginning of Gemini in line 3 to the beginning of Leo in line 5 in 50 days, fit Venus's motion in Augustus 20 (Figure 7) very well, and no other nearby year. The preserved rows must have come from the same column of the almanac as Fragment 2, but towards the bottom; in this year, the total number of sign-entry rows required for Mars and Venus should have been slightly more than

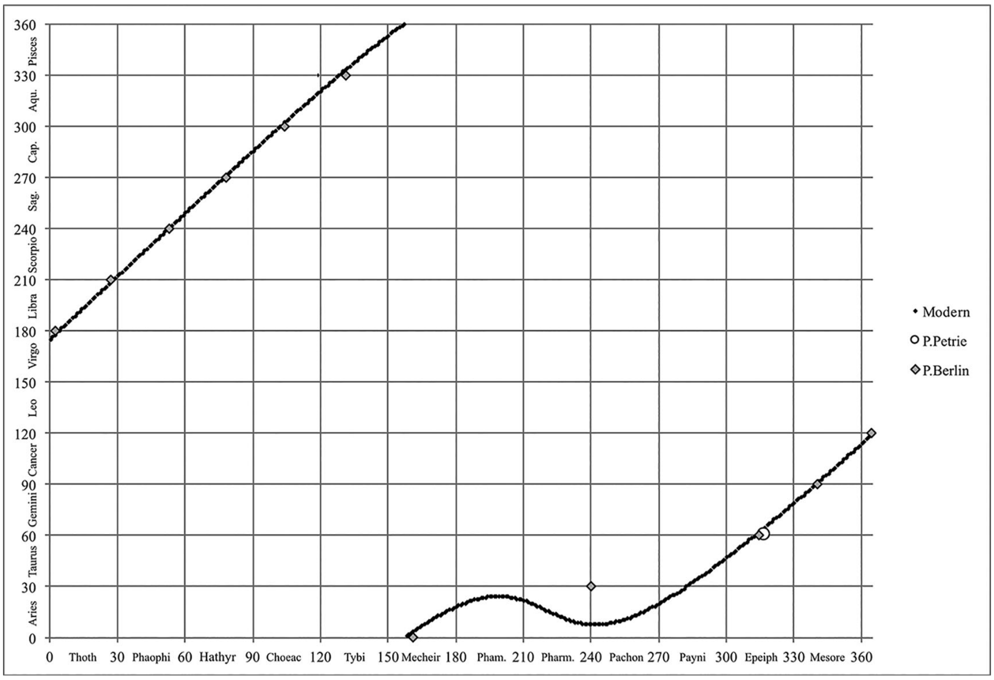

Fig. 5. Longitudinal motion of Venus in Augustus 22 (9/8 BC)
according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

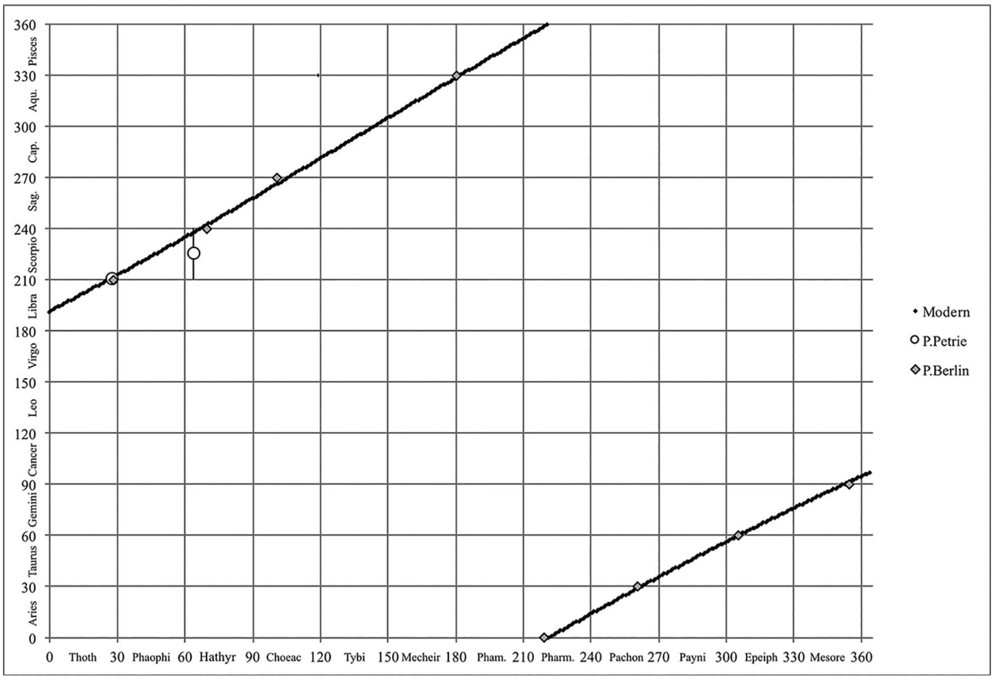

Fig. 6. Longitudinal motion of Mars in Augustus 20 (11/10 BC)
according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

twenty. Col. ii thus preserves rows shortly preceding those of Fragment 1 col. i, and so should belong to the subsection for Mars in Augustus 21. The loss of day numbers and zodiacal signs impedes detailed comparison with modern theory (Figure 8), but the long eight-month gap between the first row's date in Thoth and the second in Pachon would correspond nicely to Mars's retrogradation during Augustus 21, which was entirely within Leo. According to modern theory, sign-entries respectively into Leo, Virgo, and Libra took place on Phaophi 11, Payni 6, and Epeiph 28, while the next sign-entry into Scorpio occurred on Thoth 8 of the following year Augustus 22. No synodic events fell within the second half of Augustus 21. In the papyrus, events are recorded for Thoth, Pachon, an illegible month, and Mesore. The one in Thoth must be the entry into Leo, anticipating modern theory by a few days. The others probably pertain to the next three sign-entries, with dates similarly leading the modern-theory dates.

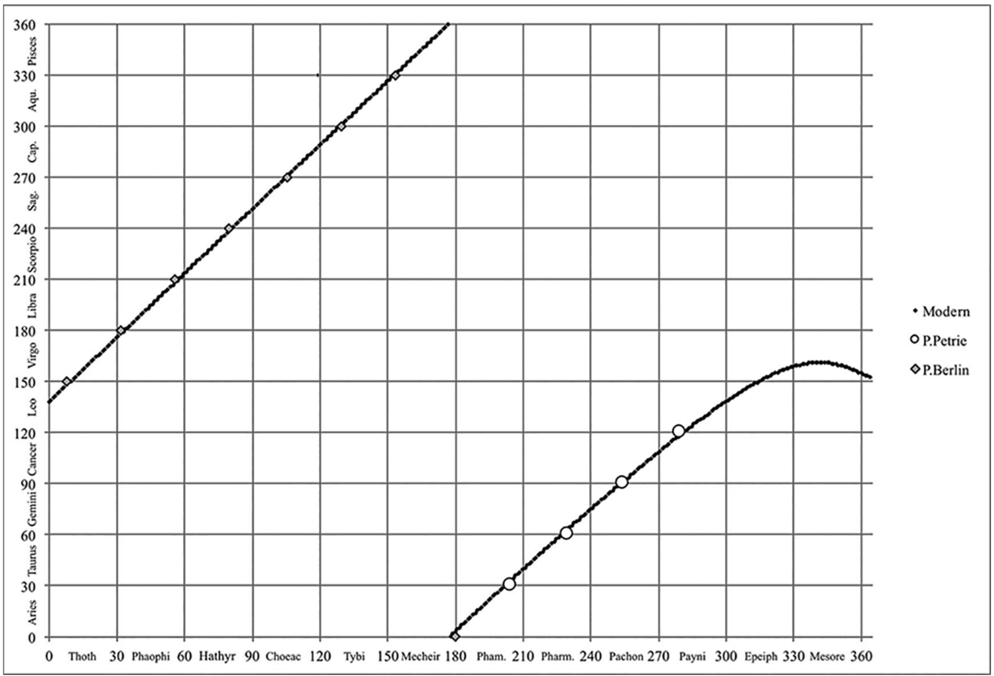

Fig. 7. Longitudinal motion of Venus in Augustus 20 (11/10 BC)
according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

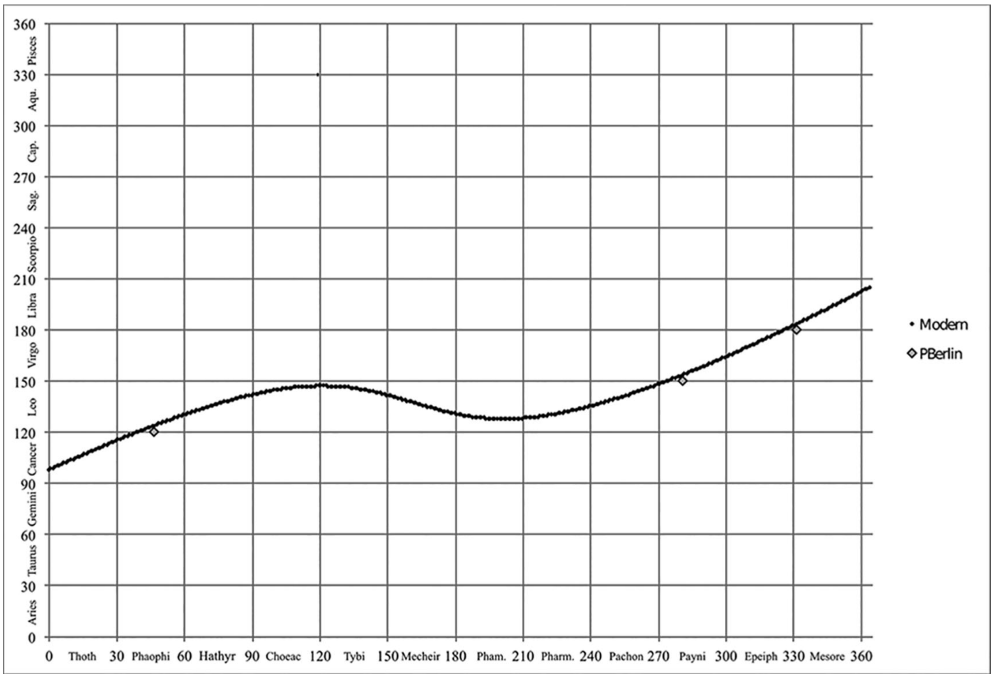

Fig. 8. Longitudinal motion of Mars in Augustus 21 (10/9 BC) according to modern theory and *P.Berlin* 8279

Fragment 4 has the header and first four rows of a subsection for Mars, minus the month names but with the planet either entering or having a synodic phenomenon in Cancer as the first event of the year. Assuming proximity to Fragments 1–3, the year in question must be Augustus 19, and the fragment probably came from towards the top of the table column two columns to the left of that of Fragment 2 and Fragment 3 col. i. We can restore the months with some confidence as, respectively, Thoth, Pharmouthi, Epeiph, and Mesore (Figure 9).

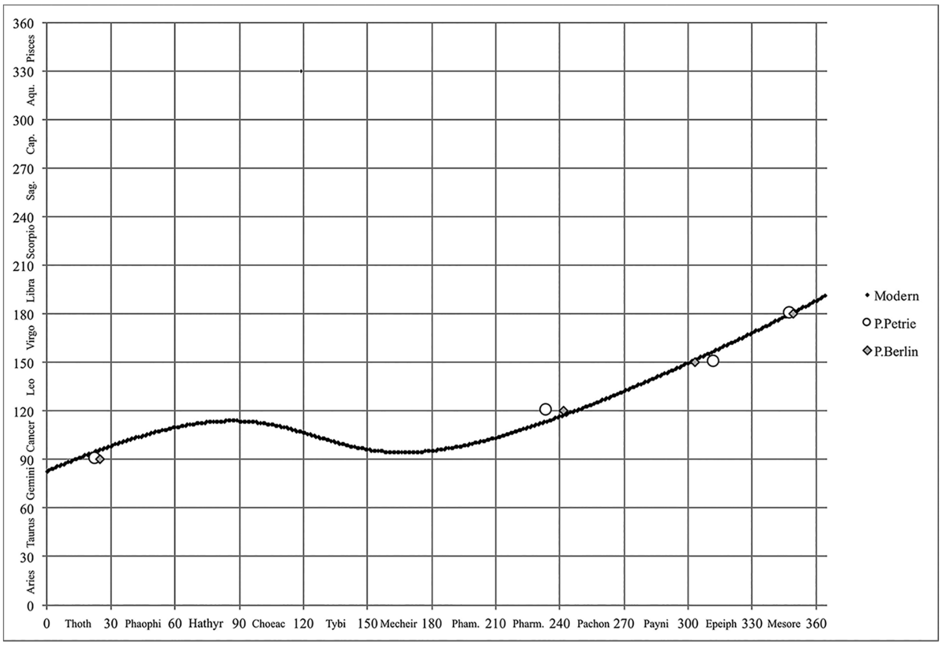

Fig. 9. Longitudinal motion of Mars in Augustus 19 (12/11 BC)
according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

The planet of Fragment 5 progresses the 30° from the beginning of Aquarius to the beginning of Pisces in 26 days, which is only possible for Venus or Mercury. The preserved data fit Venus's sign-entries equally well in either Augustus 16 or 24 (Figure 10); the later date is perhaps preferable since it would place the fragment nearer to the previously dated fragments, three columns to the right of Fragment 1 col. iii instead of five or six columns to the left of Fragment 4.

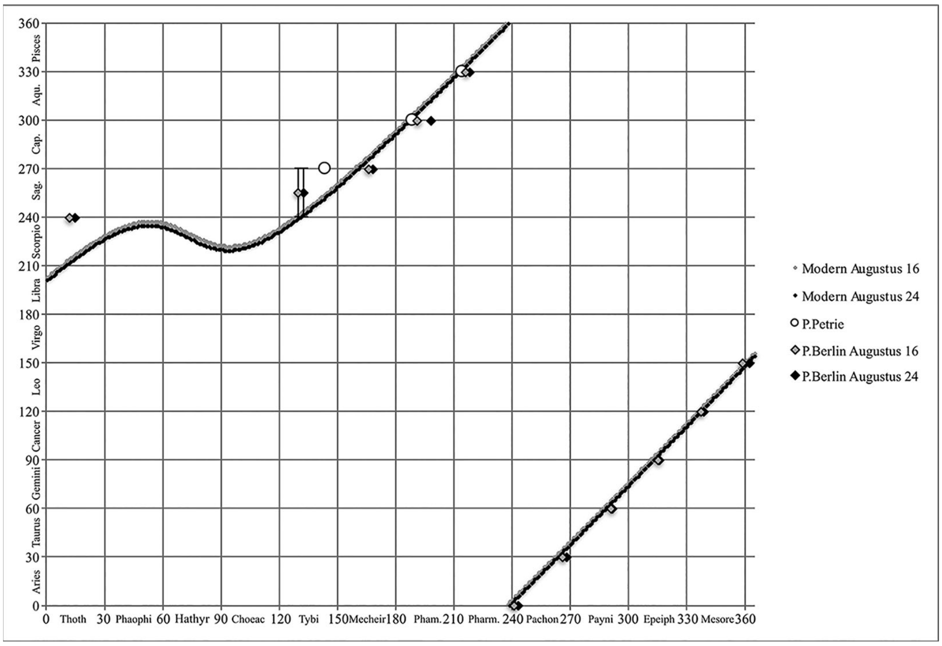

Fig. 10. Longitudinal motion of Venus in Augustus 16 and 24 (15/14 and 7/6 BC)
according to modern theory, *P.Petrie Mus. astr.*, and *P.Berlin* 8279

None of the remaining fragments provides enough information to locate them in the table. Fragments 1–5 are sufficiently spread apart so that there is no reason to expect that the smaller bits would have joined or been especially close to any of them. Depending on the year of Fragment 5, we can deduce that the almanac covered at least the years Augustus 19–24 or Augustus 16–22 (Figure 11). The data for Augustus 19 could have begun at the top of a column, so this might have been the first year of the almanac.

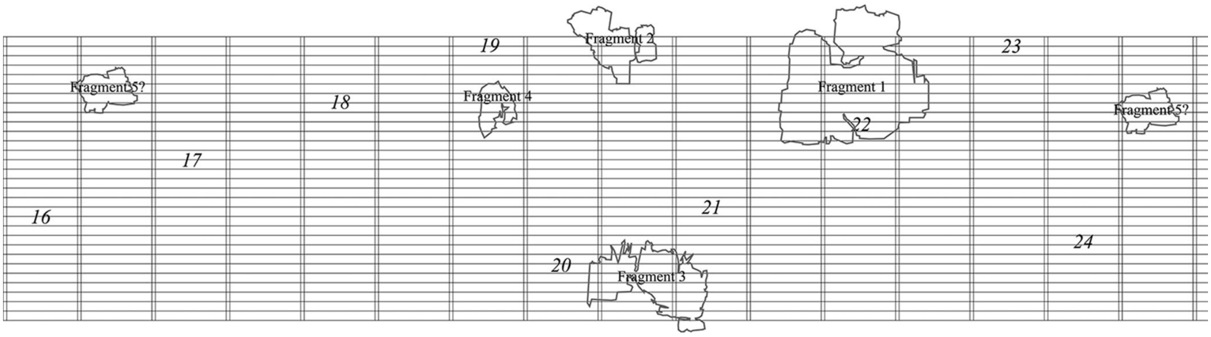

Fig. 11. Reconstruction of the papyrus roll. Italicized numerals represent the beginnings of the sections for the relevant regnal years of Augustus, estimated except in the case of Augustus 22. Locations of the papyrus fragments are also only approximate except for Fragments 1 and 2

The datable fragments all overlap chronologically with the demotic sign-entry almanac *P.Berl*. 8279, which has nearly complete coverage of Augustus 14–34 (old calendar).[11] Figures 2–10 show as small diamonds the sign-entries and other events for which this papyrus has preserved dates and longitudes. There is only a single exact coincidence between dates of the same event in *P.Petrie astr.* and *P.Berl*. 8279 (Mars's entry into Scorpio on Thoth 30, Augustus 20), but near coincidences are frequent, even when the dates diverge significantly from the modern-theory behavior of the planet in question. Thus in Augustus 21 (Figure 3) Mercury's entry into Cancer is on Payni 16 according to *P.Petrie* and Payni 15 according to *P.Berl*. 8279, about half a month later than the true entry, reflecting an inaccurate representation of Mercury's behavior around retrogradation. Venus's sign-entries during the intervals of rapid direct motion are quite consistent between the two papyri and keep close to the dates according to modern theory (Figures 7, 4, and 5, in chronological order). That the discrepancies are slightly larger for Mars (Figures 9 and 6) and Saturn (Figure 2) is merely a consequence of the slower motion of those planets. Broadly speaking, the computed positions in both papyri appear to be derived from tables whose underlying assumptions were roughly the same as well as being reasonably correct for most dates.

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Gaia Fanelli, Alma Mater Studiorum, Università di Bologna
gaia.fanelli2@unibo.it
Alexander Jones, Institute for the Study of the Ancient World, New York University
alexander.jones@nyu.edu

[11] Edition in Neugebauer–Parker 1969, part 2, plates 70–73.