On the Planetary Table, Dublin TCD Pap. F. 7

In the original publication of this fragment, F.A.J. Hoogendijk tentatively identified the contents of its four partially preserved columns as longitudes of Venus on consecutive days.[1] Subsequently I developed this hypothesis by proposing a reconstruction of the pattern of motion assumed for Venus and attempting to relate it to various schemes for predicting Venus's motion in Babylonian astronomical texts.[2] Although this reconstruction seemed plausible, and indeed necessary on the assumption that the planet concerned throughout the table was Venus, there were two difficulties with it. First, there are no indications of dates beside the tabulated longitudes. This I accounted for by supposing that the table was laid out according to a regular calendrical structure so that a single index column, now lost, could count the days for all columns simultaneously. The intervals of time needed between consecutive columns in order to make sense of their contents as positions of Venus would have been approximately 60 days, or two Egyptian months, and this would imply a large, but by no means impossible, height for the complete papyrus. Secondly, the daily (i.e. line-to-line) progress in the last preserved column (D) is between 1° 22' and 1° 32', whereas Venus never travels faster than about 1° 15' per day. I was compelled to ascribe this inconsistency to a systematic error made by the computer of the table. We know of no comparable papyrus table of a single planet's daily positions, but this was a consideration of little weight, given the still modest number of published astronomical papyri of all kinds.

Nevertheless TCD Pap. F. 7 bears an outward resemblance to certain other papyrus tables known as ephemerides, which tabulate the daily longitudes of all the heavenly bodies (moon, sun, and five planets) in parallel columns laid out according to single calendar months.[3] The published specimens of this kind of table, both comparatively late, are P. Mich. inv. 1454, for A.D. 467, and P. Vindob. inv. 29370, for A.D. 489.[4] Aside from the similarity of layout, a further reason suggesting that TCD Pap. F. 7 might be a general ephemeris is that the line-to-line increments in the four columns make good sense as daily progress of the planets Jupiter, Mars, Venus, and Mercury, following the standard order of Greek astronomical and astrological texts. Thus the differences between lines in Column B are consistently 0° 44' or 0° 45', which is approximately Mars's daily progress during long stretches of its

[1] F.A.J. Hoogendijk, "Fragment of a Greek Planetary Table", *ZPE* 48 (1982) 135-141 and plate VI.

[2] A. Jones, "A Second-Century Greek Ephemeris for Venus", *Archives Internationales d'Histoire des Sciences* 41 (1991) 3-12.

[3] The possibility that TCD Pap. F. 7 is an ephemeris for all the planets was raised but then rejected by Hoogendijk, pp. 137-138, for reasons that in retrospect do not appear adequate.

[4] H.D. Curtis and F.E. Robbins, "An Ephemeris for 467 A.D.", *Publications of the Observatory of the University of Michigan* 6.9 (1935) 77-100; H. Gerstinger and O. Neugebauer, "Eine Ephemeride für das Jahr 348 oder 424 n. Chr. im Pap. Graec. Vindob. 29370", *S.B. Akad. d. Wiss. Wien, phil.-hist. Kl.* 240.2 (1962) 1-25. For the date and format of the latter, see now A. Jones, "Two Astronomical Papyri Revisited", forthcoming in *Analecta Papyrologica*. A different variety of ephemeris is also now known, for which see A. Jones, "An Ephemeris for A.D. 140: P. Harris I.60", *ZPE* 100 (1994) 59-63.

fastest motion; the retrograde motion between 0° 23' and 0° 24' in Column B is appropriate for Venus; and progress between 1° 22' and 1° 32' (Column D) is well within Mercury's range of velocities. Column A, where only the minutes and traces of the degrees are preserved, can be restored to represent Jupiter's slowing motion (0° 9' per day declining to 0° 8' per day) as it approaches first station:

1	λ]ō	30] 0
1a	ἰχθύων	Pisces
2	ọ̄ θ	0 9
3	ọ̄ ιη	0 18
4	ọ̄ κς	0 26
5	ō] λε	0] 35
6	ō] μγ	0] 43
7	ō] να	0] 51
8	ọ̄ νθ	0 59
9	α] ζ	1] 7

The test of whether the columns of the table pertained to these four planets will be to seek an acceptable date for which the planets' positions and speeds fit the contents of the papyrus. On paleographical grounds Hoogendijk dated the fragment to the second century, but given the difficulty of dating numerical tables by hands, we may take a more generous range of dates, encompassing the first five centuries of the Roman period, i.e. 30 B.C. through A.D. 470. The days in question will have to belong to the end of a month in an appropriate civil calendar. All the published ephemerides are laid out according to the months of the Roman calendar. If our table sets out the planets' longitudes during a Roman month, it must be one with an even number of days since the last "cell" of each column, although a little taller than those above, contains only two lines of numbers. We may also consider as a candidate the Alexandrian calendar; the old Egyptian calendar with constant years of 365 days, although often applied in astronomical computations during the Roman period, is much less likely to have been used in a calendrical table than one of the civil calendars. Moreover the time of year can be determined roughly from the assumption that Jupiter is approaching first station in Pisces with a velocity of about 9' per day; this is only possible between March and May. Hence the only months worth investigating are Alexandrian Phamenoth, Pharmuthi, and Pachon, and Roman April.

Planetary longitudes for antiquity computed according to modern astronomical theory are most easily obtained from Tuckerman's tables.[5] I preferred, however, to use a computer program designed to reproduce predictions according to Ptolemy's *Handy Tables*, which more nearly represent ancient assumptions about planetary motion, and I furthermore applied Theon of Alexandria's formula to convert Ptolemy's tropical longitudes to the sidereal longitudes more commonly found in ancient tables and horoscopes.[6] Given the low precision required for

5 B. Tuckerman, *Planetary, Lunar, and Solar Positions 601 B.C. to A.D. 1* Memoirs Am. Phil. Soc. 56 (Philadelphia 1962), and *Planetary, Lunar, and Solar Positions A.D. 2 to A.D. 1649*, Memoirs Am. Phil. Soc. 59 (Philadelphia 1964).

6 The rule is to add 8°, and then subtract 1/80 of a degree for every year elapsed since 158 B.C.

our purposes, however, either method would yield nearly the same results. Using the last lines of the papyrus as a target to match, I computed planetary longitudes for the 29th and 30th of all the possible months throughout the 500-year range, picking out only those pairs in which Jupiter was within 11° of Pisces 1° (i.e. between 320° and 342°) and Venus was moving retrograde. The admissible dates were as follows:

	Jupiter	Mars	Venus	Mercury
Papyrus, lines 8-9 (zodiacal signs	330° 59'	6° 24'	17° 9'	26° 4x'
undetermined except Jupiter)	331° 7'	7° 8'	16° 46'	28° 12'
1. 41 March 25/26	325° 26'	153° 18'	355° 51'	352° 40'
= Phamenoth 29/30	325° 38'	153° 4'	355° 18'	354° 32'
2. 65 March 25/26	333° 30'	64° 43'	346° 11'	344° 32'
= Phamenoth 29/30	333° 43'	65° 17'	345° 51'	344° 18'
3. 89 March 25/26	341° 31'	11° 31'	337° 56'	20° 14'
= Phamenoth 29/30	341° 45'	12° 15'	337° 51'	21° 46'
4. 100 April 24/25	322° 42'	358° 15'	56° 58'	46° 20'
= Pharmuthi 29/30	322° 51'	359° 0'	56° 51'	48° 6'
5. 124 April 24/25	331° 20'	269° 59'	49° 14'	13° 4'
= Pharmuthi 29/30	331° 30'	270° 21'	48° 51'	14° 42'
6. 148 April 24/25	339° 49'	112° 45'	39° 56'	43° 5'
= Pharmuthi 29/30	340° 1'	113° 12'	39° 22'	42° 26'
7. 100 May 24/25	326° 15'	20° 21'	42° 40'	80° 51'
= Pachon 29/30	326° 19'	21° 5'	42° 18'	80° 42'
8. 124 May 24/25	335° 40'	275° 49'	34° 50'	68° 13'
= Pachon 29/30	335° 46'	275° 50'	34° 43'	70° 6'
9. 100 April 29/30	323° 27'	1° 59'	55° 54'	54° 58'
	323° 36'	2° 44'	55° 32'	56° 37'
10. 124 April 29/30	332° 11'	271° 34'	46° 58'	21° 33'
	332° 21'	271° 50'	46° 25'	23° 21'
11. 148 April 29/30	340° 46'	115° 11'	36° 55'	38° 56'
	340° 58'	115° 41'	36° 16'	37° 57'

Taking the desired velocity of Mars into consideration, we can eliminate possibilities 1, 5, 8, 10, and 11. Similarly, disagreement with Mercury's expected velocity eliminates possibilities 2, 6, and 7. In possibility 3 the retrograde velocity of Venus is much too small, and Jupiter's speed is rather too large. The remaining two dates (possibilities 4 and 9) are just a few days apart in A.D. 100, and both get all the velocities close to those of the papyrus.

We have so far reduced the possible dates for the papyrus ephemeris—presuming that it is one—by means only of the velocities of the four planets. It remains to compare their actual positions in the zodiacal signs with the numbers recorded in the papyrus. The differences between text and recomputation for the two dates are as follows:

	Jupiter	Mars	Venus	Mercury
4. 100 April 25 = Pharmuthi 30	8° 16'	8° 8'	−10° 5'	10° 6'
9. 100 April 30	7° 31'	4° 24'	−8° 46'	1° 35'

The positions for April 30 are all nearer to the longitudes in the papyrus, and are within the rather lax tolerance (±10° or so) that one has to allow for computed planetary positions before the adoption of Ptolemy's tables. Also arguing for April 30 is the evident preference for using the Roman calendar in other papyrus ephemerides. Indeed, the wider space between the bottom two rulings was surely intended to make room for a line for a 31st day, a provision only necessary if the calendar was Roman.

In conclusion, the interpretation of TCD Pap. inv. F. 7 put forward here is in every respect preferable to the former identification as an ephemeris for Venus alone; and of course the historical inferences I drew from it must also be disregarded. The preserved fragment probably covers the last days of April, A.D. 100, and except for the fact that it is not a codex, the format is (so far as one can tell) essentially the same as that of the fifth-century specimens.

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