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Thomann, Johannes

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An Arabic Ephemeris for the Year 1026/1027 CE. in the Vienna Papyrus Collection

Johannes Thomann
University of Zurich, Zurich, Switzerland

In the history of Ancient Greek astronomy, papyrus documents play an eminent role. A first landmark in this field was the book "Greek Horoscopes" (Neugebauer et al. 1959). Forty years later, a second landmark were the two volumes "Astronomical Papyri from Oxyrhynchus" (Jones 1999). Most of these astronomical documents were found in the dry soil of Egypt. They form a small part of about 150'000 Greek documents, which are preserved in Papyrus collections all over the world. It may be less known that an approximaltely equivalent number of Arabic documents on papyrus and paper are kept in the same collection. They cover a time-span from the 7th to the 15th century.

In contrast to the well established disciplin of Greek Papyrology, the sister discipline Arabic papyrology played a marginal role within Arabic Studies despite the enduring efforts of a handful of pioneers, but in recent years important steps towards institutionalsation were made. Research groups are based in Zurich, Munich, Vienna and Leiden. But this research is focused on letters and administrative documents, and the history of science is not on the top of the agenda.

Some years ago, a search for astronomical documents was started in the Vienna Papyrus collection and a few other collections. This task turned out to afford much patience, since astronomical items are extremely rare among Arabic papyri and paper documents. In this paper a fragment of an astronomical ephemeris will be presented. Hopefully, it will be shown, that even such a tiny piece of paper can cover a gap in our image of the history of astronomy in Egypt.

In order to estimate the significance of the Arabic astronomical documents from Egypt one has to bear in mind that the tradition of mathematical astronomy broke off in the Mediteranean in the 7th century. The revival of mathematical sciences took place in the extreme East of the Islamic World after the middle of the 8th century. The earliest astronomical works in the Arabic language were translations from Sanskrit and Pehlevi. Only two generations later, Greek astronomical works were translated into Arabic and astronomers in Baghdad started with new observations. Most of these scholars came from Central Asia, Afghanistan and Iran to the center in Iraq, while Egypt played no role at all. First evidence of astronomical activities in Islamic Egypt is a horoscope on papyrus probably cast for a date in the year 894 CE (Thomann 2012). This fragment does not contain any positions in degrees, and therefore, nothing can be said about the underlying technique. The same is true for an astronomical almanach for the year 910 CE (Thomann 2014b). More informative is an ephemeris for the year 931 CE (Thomann 2014a). Its analysis has shown, that outdated astronomical tables were used, which yielded considerable errors in the position. As it seems, these tables were calculated for the meridian of Merw in Turkmenistan and were compiled at the beginning of the 9th century. This sheds no favorable light on the level of

knowledge in Egypt at that epoch, and suggests that the more advanced works of Ḥabash and al-Battānī were not know there.
In the decennies to follow, the advent of the Fatimids caused groundbreaking changes in Egyptian society and culture. New institutions of learning were created (Halm 1997), and under the rule of al-Ḥākim Ibn Yūnus compiled astronomical tables which were much admired in later time (King 1972). It would all the more important to have documentary evidence on how all this affected astronomical practice. Luckily, the ephemeris presented here fullfills this purpose perfectly.
The document P. Vind.Inv. A.Ch. 25613 g is a small piece of paper containing the top left corner of a table on the recto, and the top right corner of the following table on the verso. On the verso the headers of the calendarium and the first three lines are peserved containing the dates of the first three days of the month. In the headers the four calendars are named: (i) *fārsī*, the Persian calendar, (2) *suryānī*, the Syriac calendar, (3) *qibṭī*, the Coptic calendar, and (4) *ʿarabī* , the Islamic calendar.
The Persian calendar was base on a wandering year with a constant length of 365 days without intercalation, similar to the ancient Egyptian calendar. The first year of the reign of the last Sassanian king Yazdgird III was used as the epoch, and its beginning fell into the Julian year 632.
The Syriac calendar was equivalent to the Julian calendar, but used the Syriac names of the months, and was based on the Seleucid era.
In Coptic calender the names and lenghts of the months corresponds to those in the Ancient Egyptian calendar, but an intercalation of one day every four years was used.
The Islamic calendar was a Lunar calendar based on the observation of the Lunar crescent, but in astronomical works a cyclical system of 30 year periods was used as an approximation. Day-numbers in all four calendars even without the names of the months are sufficient for a sure absolute dating (Thomann 2014a). The first line corresponds to the ninth of May 1026 CE. The column to the left contains the days of the week, encoded in numbers running from 1 to 7. The ninth of April 1026 was a Monday, as indicated by the number 2. All figures are written with Arabic letters in the so-called *abjad* system, which is similar to the Greek system of writing numbers by letters of the alphabet.
There is one seeming irregularity in the calendar data. The dates in the Arbic column are one day ahead in comparision to the most commun calculation scheme for the Islamic calendar. However, already in the 9th century, Ḥabash al-Ḥāsib reported a controvery about the epoch of the calculated calendar and criticized scholars who used an epoch earlier by one day (MS Istanbul Yeni Cami 784 ff. 75v; cf. Debarnot 1985, 39). However, al-Battānī used the earlier epoch in their tables (Nallino 1899–1907, 7–17).
On the recto the upper left corner of the table covering the preceding Persian month is preserved. The lines correspond to dates which preceds the days on the verso by 30 days, starting at the 9th of April 1026 CE. The headers of the last two columns are (i) *irtifāʿāt*, “altitudes”, and (2) *sāʿāt al-nahār*, “hours of the day”. They contain the altitude of the sun at noon and the length of the day. These data provide valuable information on the geographical latitude and the values of the ecliptic longitudes of the sun.
The altitude of the sun at noon is equal to the complement of the polar height plus the declination of the sun. Since there is no a priori knowledge about the geographical latitude for which the table was calculated, the shares of the declinations of the sun are not immediately known. Nevertheless, the daily differences are independent from the

geographical latitude. There were two values of the obliquity of the ecliptic in use, the Ptolemaic value of 23° 51' and the new value of 23° 35' based on observations in the 9th century (Britton 1969, 30; Dalen 2004, 18–21). Consequently, both values must be considered in the analysis. Furthermore, depending on the underlying tables for solar motion a different amount for the daily change in longitude must be assumed. In brief, the analysis shows that the declination of the sun in the middle to the three days must be in the intervall of 8°55' and 10° 32', and therefore the geographical latitude, for which the table was calculated in the interval of 28° 53' and 30° 30'. This makes almost certain that the intended place was Cairo, for which a latitude of 30° 00' was used (Nallino 1899–1907: ii 32). This assumption allows for a more precise estimate of the solar longitudes. Comparing them with the values obtained by the tables of Ptolemy, al-Khwārizmī and al-Battānī, the last tables yield the closest fit (Toomer 1995, 142–143, 167; Suter 1910, 115–116, 132–137; Nallino 1899–1907, ii 10–23, 78–83). However, it seems that the underlying values are even closer to the precise values than those of al-Battānī. Based on this evidence, it seems likely that an advanced astronomical work was used. A promissing candidate are the Ḥākimite Tables of Ibn Yūnus.

Based on the assumed geographical latitude of Cairo, the values for the length of the day can be used for a test if the tables of Ibn Yūnus would have produced these values. The tables themselves are not edited, therefore the parameters mentioned in the earlier chapters were used (Caussin 1804: 216; Delambre 1819: 93–94). The solar longitude on the 9th of April according to a calculation with this parameters was 24° 37', a value 36' less than the value of al-Battānī. The corresponding values for the lenght of the day are 12h 45m and 12h 46m respecively. Ibn Yūnus' value matches exactly the value tabulated in our ephemeris. The difference of one minute is small and more tests have to be made in order to decide which astronomical tables were used in compiling these ephemeris, but at the moment it seems likely that indeed Ibn Yūnus' tables were the basis for calculation.

A priori, it can not be taken for granted that the best available tables were use for calculations. A horoscope for 17th of June 1082, found in the Cairo Geniza, contains an explicit statment that the Sindhind was used for its calcualtion (Goldstein 1977, 116-121). The first explict documentary reference to Ibn Yūnus occurs in a horoscope for 11th March 1122 (Goldstein 1980, 158–160). There, the compiler wrote: “All of it from the Zīj of our master, the Imām al-Ḥākim bi-Amr Allāh, blessings of God upon him.” Goldstein and Pingree made the assumption that two more horsocopes and a group of astronomical almanachs from the time-span of 1132 to 1158 CE were calculated by means of the Tables of Ibn Yūnus (Goldstein 1979, 153). In none of the cases did they provide calculations with different sets of parameters, but they based their assumption on an account of al-Maqrīzī on the founding of the Cairo Obervatory in 1120 CE.

If the analysis presented above is correct, the ephemeris of 1026 CE would shift documentary evidence for the use of the Hākimite tables of Ibn Yūnus back by one century and prove that they were used in practice very soon after their completion.

There is one column left on the recto. Its header indicates that it contains the position of the ascending lunar node, the *jawzahar*. Only the zodiacal sign Scorpion and the values for the arc minutes are preserved. The degrees are missing with the exception of a trace of inc slightly below the writing line. I might have belonged to 6 or 7 as the last digit. If 7 is assumed, the values are very closed to the precise values, but they dont match exactly the values obtained by means of the tables of al-Battānī (Nallino 1899–1907, ii 72–77). In the

edited part of the tables of Ibn Yūnus the mean movement of the lunar node is 19° 19' 44" 21''' 48'''' in a Persian year (Caussin 1804, 216–217). In the unedited part of the tables, the complement of the longitude of the lunar node at 30 November 1000 CE is referred to as 11^{s} 21° 27' 3" 33''' (Caussin 1804, 222). However, this last value is less accurate than the value according to a calculation with al-Battānī's table. Therefore, Caussin's reference seems doubtful. An attempt to find this value in the MS Leiden Or. 143 failed, but the question needs further investigation. The marginal notes are difficult to decipher, a situation which is not uncommun in such documents. In the right and the left margin, additional events like religious feasts would be expected, but no clue to the reading of these notes could be found.
The analysis of the document so far alows for a reconstruction of the entire document. Probably it was a booklet of 26 pages at least with tables for the twelve months of the Persian year 395, which corresponds to 10th March 1026 to 9th March 1027. Each bifolium covered one month. It started with the five narrow column for the calendar data, followed by columns for the sun, the moon, Saturn an Jupiter. On the left page of the bifolium followed Mars, Venus, Mercury and the lunar node. At the end were the two colums for the altitude of the sun at noon and the lenght of the day.
There exists a complete copy of an ephemeris of this type for the year 1326/1327 in the Dār al-Kutub in Kairo (King 1986, 132; King 2004–2005, ii 421, erroneously labeled “Ramaḍān 808 H.”). It represents a new type since it combines an ephemeris with astrological predictions, the *ikhtiyārāt*. Furthermore, it is organizded by the Islamic calendar. However, for the question, how ephemerides in the classical Islamic period looked like, the study of fragments like the one presented here is indispensible.

iv	iii	ii	i	r°
Al-jusʾu bi-l-*th*awr h *j* [..]				1
	sāʿāt al-nahār	al-irtifāʿ	al-jawzahar	2
			al-ʿaqrab	3
	yb mh	sṭ mʾ	[kz] mw	4
	yb mw	ʿ b	[k]«z» mj	5
	yb mḥ	[ʿ] kd	[kz ..]	6
«...»	[.. ..]	[.. ..]	[kz ..]	7

vi	v	iv	iii	ii	i	v°
ikhrāj rabīʿ al-ākhar ..						1
ay ā m	ʿar ab ī	qi bṭī	su ry	fār si		2
b	yṭ	yd	ṭ	ʾ		3
j	k	yh	y	b	...	4
[d]	kʾ	yw	yʾ	j		5
[h]	[kb]	[yz]	[yb]	[d]	...	6

r°	I	ii	iii	iv
1	[..] the part in [the zodiacal sign of] Taurus 5° 3'			
2	Lunar node	the altitude	hours of the day	
3	[Zodiacal sign of] Scorpion			
4	[27°] 46'	69° 41'	$12^h 44^m$	
5	[2]«7»° 43'	70° 2'	$12^h 46^m$	
6	[27° ..']	[70°] 24'	$12^h 48^m$	
7	[27° ..']	[70° ..']	[$12^h ..^m$]	«...»

v°	i	Ii	iii	iv	v	vi
1	Beginning (?) of [the month] Rabīʿ I					
2		Persi	Syriac	Coptic	Arabic	Days of Co
3		1	9	14	19	2
4	...	2	10	15	20	3
5		3	11	16	21	[4]
6	...	[4]	[12]	[17]	[22]	[5]

Table 1: *Edition and translation of the document P. Vind. Inv. A.Ch. 25613 g*[1]

[1] Letters in red are underlined, ascendingly slanted words have a line above, and decendently slanted words have a dotted line above. Letters with diacritical dots are in italics. Words within «» are difficult to read.

Figure 1: *recto of Vind.Inv. A.Ch. 25613 g (courtesy Papyrussammlung der Österreichischen Nationalbibliothek)*

Figure 2: *Verso of Vind. Inv. A.Ch. 25613 g (courtesy Papyrussammlung der Österreichischen Nationalbibliothek)*

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