4.12 A MOORISH ASTROLABE FROM GRANADA

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In the course of a systematic search in the "Technical Museum" of Vienna for instruments of astronomical importance, a Moorish astrolabe with Cufic lettering was discovered by the present author. Being labelled as "sun-moon-dial" its correct function had not been recognized before or forgotten. The device came into the museum's possession in April 1937 through exchange with a theodolite from the Jesuit College at Kalksburg where the astrolabe had been kept after it remained in Vienna during one of the two Turkish sieges of the city (probably in 1683).
The brass instrument has a diameter of 15,7 cm and is well equipped with 8 ṣafīḥas (= tympans). Its conservation state is rather good,even the original red and gold ʿilāqa (= cord) is in place. The specimen is of undated planispheric northern type (shamālī musaṭṭah). It shows the typical small kursī (= throne) of occidental instruments, cast in one piece with the ḥajra (= limb) and umm (= mater) forming the main body of the astrolabe. This fact sets it apart from instruments of European origin where the kursī sometimes was fastened with screws to the main body (W. Morley, reprinted in R. Gunther, 1976).
While the front side displays a 360 degree division on the limb, inscribed in quadrants, the umm only shows the tropic of Capricorn, the equator and the circle of the tropic of Cancer. On the rear side, besides another subdivision into degrees, the zodiacal signs are marked also by their astrological symbols . Also a solar calendar circle is shown. Some of the months have been lettered later in Latin writing, most probably indicating Provençalic language (derived from 'OTTO' as shortening for October). 1st of Aries coincides with March 13th placing the object in the first half of the 13th century if this fact can be attributed to the actual date of fabrication. However the instrument may have been produced later, if only an earlier design had merely been copied. Inside the innermost circle with 28 subdivisions the shadow scales for direct and inverted shadow are given in 4 x 3 degrees for terrestrial use. One of the diopters of the ʿiḍāda (the alidade) is missing.

The ʿankabūt (= rete) gives 13 star names inside the ecliptic and 15 outside, a list of which is provided in Table 1.

The 8 ṣafīḥas, each with a diameter of 13,8 cm and a thickness of 0,25 mm (only plate number 4 measures 0,4 mm) are labelled according to the cities and their latitudes for which they are constructed. Somebody has scratched

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Table 1. STAR-IDENTIFICATION ON THE RETE

Nr.	Stars inside the zodiac		Nr. according to Kunitzsch (1959)
1	jaḥfala	ε Pegasi	58
2	tāʾir	α Aquilae	54
3	ḥawwāʾ	α Ophiuchi	51
4	ʿaṭfat al-ḥayya	δ Serpentis	-
5	mankib al-faras	β Pegasi	62
6	al-ridf	α Cygni	56
7	al-wāqiʿ	α Lyrae	53
8	al-fakka	α Coronae Borealis	45
9	al-ramiḥ	α Bootis	41
10	al-dubb	μ Ursae Majoris	-
11	wasaṭ al-saraṭān	ι Ursae Majoris(?)	-
12	al-ʿayyūq	α Aurigae	20
13	raʾs al-ghūl	β Persei	14

Nr.	Stars outside the zodiac		Nr. according to Kunitzsch (1959)
1	ḏhanab al-jady	δ Capricorni	59
2	ḏhanab qayṭūs	β Ceti	8
3	baṭn qayṭūs	ζ Ceti	6
4	al-jaḏhmāʾ	α Ceti	13
5	rijl al-jawzāʾ	β Orionis	19
6	ʿabūr	α Canis Majoris	23
7	raʾs shujāʿ	σ Hydrae	-
8	shujāʿ	α Hydrae	29
9	al-ghurāb	γ Corvi	36
10	al-aʿzal	α Virginis	39
11	qalb al-ʿaqrab	α Scorpii	48
12	dabarān	α Tauri	18
13	mankib	α Orionis	22
14	ghumayṣāʾ	α Canis Minoris	25
15	zubānā	α Cancri	-

their Latin names into the lower parts of the corresponding plates. The numbers of the tympans have been crudely cast into the plates, probably when the instrument was registered as museum specimen.

Plate 1a) carries the following inscription: Latitude of Al-Jazīra and the whole province, its latitude is $39^{\circ}30'$ (this neither

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fits to Algiers nor Algeciras).

1b) On the rear side the inscription reads: for the latitude of Merida and the whole province, latitude $42^{o}30'$. Here European numerals are written to explain the Cufic ones. Both sides show, besides the usual azimuth and almucantar lines of sudsi - type (with 15 lines marking 6 by 6 degrees) also the lines of the unequal hours plus the information of midday and afternoon prayer times as dotted lines.

Plate 2a) shows the almucantars below the ufq (= horizon) as also known for the Great Astrolabe of Jaipur (V. Nath Sharma, 1984) but for a high geographical latitude. The inscription reads: Longitude of the stars and their latitude.

2b) gives the information that it is constructed for $37^{o}30'$ northern latitude (which is the value for Granada) and contains astrological information showing the 12 celestial houses divided into 36 parts, consecrated to the 36 decans.

Plate 3a) also shows the celestial house lines for the latitude of $37^{o}30'$ while the text reads: according to the layout of Hermes (Trismegistos, see also J. Samso, 1973). The ordinal numbers start from the horizon line marked "East" on the left side of the plate and run counterclockwise.

3b) is part of a tablet of horizons showing only one horizon line which in accordance with the geometry (H. Michel, 1947) was recomputed by the author to give $44^{o}27'36''$. Possibly the tympan was carved by its last Turkish user and could have served with tolerable accuracy for the latitude of Vienna too.

Plate 4a) again states " for the latitude of Granada and the whole province, latitude: 37^{o} 30'." Temporal hours and prayer lines are given also. From the overabundance of latitude $37^{o}30'$ it can be deduced, that the instrument most probably was produced in Granada.

4b) is a tablet of horizons for all latitudes of the typical occidental style according to the Andalusian astronomers Alī b. Jalaf and Arzaquiel, stating " for all latitudes".

Plate 5a) is " for the latitude of Mālaqa, 37^{o} " (which would be incorrect).

5b) is " for the latitude of Almeria, 36^{o} " (which also is incorrect).

Plate 6a) " For the latitude of Mecca, $21^{o}30'$."

6b) " For the latitude of Aleppo, 35^{o} ."

Plate 7a) " For the latitude of Cufa, $31^{o}30'$. "

7b) " For the latitude of Sabta (= Ceuta), $35^{o}30'$. "

Plate 8a) " For the latitude of Fas (= Fez), $33^{o}30'$. "

8b) " For the latitude of Marrakesh (Morocco), $30^{o}30'$."

As stereographic projection is used for the conception of an astrolabe, the linear distance m between the zenith and the north pole(= center of each tympan) measured in units of the radius r of the equator circle, can be used to estimate the actual geographic latitude for which the tympan was laid out according to the formula:

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$$\varphi = 90^{\circ} - 2 . \arctan \left(\frac{m}{r}\right) \quad . \tag{1}$$

The root mean square error $\Delta\varphi$ for the reconstruction of φ for each plate can be obtained from:

$$\Delta\varphi = \frac{360^{\circ} . \Delta x}{\pi \sqrt{1 + \left(\frac{m}{r}\right)^2}} \tag{2}$$

where $\Delta x = 0.01$ cm is the precision of the actual measurements. Having reconstructed the latitudes from the tympans, some were compared to modern values to get an idea of their internal accuracy.

Table 2. COMPARISON Of RECONSTRUCTED LATITUDES AND ERRORS

Tympan Nr.	Latitude inscribed	Latitude reconstructed	rms error $\Delta\varphi$
1 front	39°,5	39°,30	1°,03
1 rear	42	41,17	1,04
2 front	-	65,98	1,12
2 rear	37,5	38,30	1,03
3 front	37,5	-	-
3 rear	-	44,46	1,05
4 front	37,5	36,42	1,02
4 rear	-	-	-
5 front	37	35,90	1,02
5 rear	36	34,62	1,01
6 front	21,5	20,40	0,94
6 rear	35	35,38	1,02
7 front	31,5	31,85	1,00
7 rear	35,5	33,98	1,01
8 front	33,5	32,10	1,00
8 rear	30,5	29,40	0,99

The error of the reconstructed latitudes versus the inscribed ones shows the limited precision which was obtained by the astrolabist in manufacturing the instrument. No indication of the craftmanship is mentioned and nothing is known how it came into the possession of the Turks besieging Vienna and why such a precious device was left back by its proprietor. The author owes a hint to J. Samso (1985) that there might be a connection of this astrolabe to Hasan b. Muhammad b. Baso who was chief of the time-reckoning service at the grand mosque of Granada and died 716/ 1316 - 1317.

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Fig. 1: Backside of the Moorish astrolabe.

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DISCUSSION

M.A.N.Mohammed : What was the zero longitude on these astrolabe ?

Maria Firneis : It was not measured by now.

S.N.Sen : Does the astrolabe have latitude and longitude of places inscribed in the mother ? Have you measured the coordinates of the stars inscribed in the ankābut from the ṣafiha mīzān al-ankabūt! and from there date of the astrolabe.

Maria Firneis : These coordinates have not been measured, but may not be correct indicators for dating, as astrolabists quite often copied older instruments. Also the positions on the 'Aṅkābut' sometimes are bent, a fact that makes dating even more uncertain.

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