

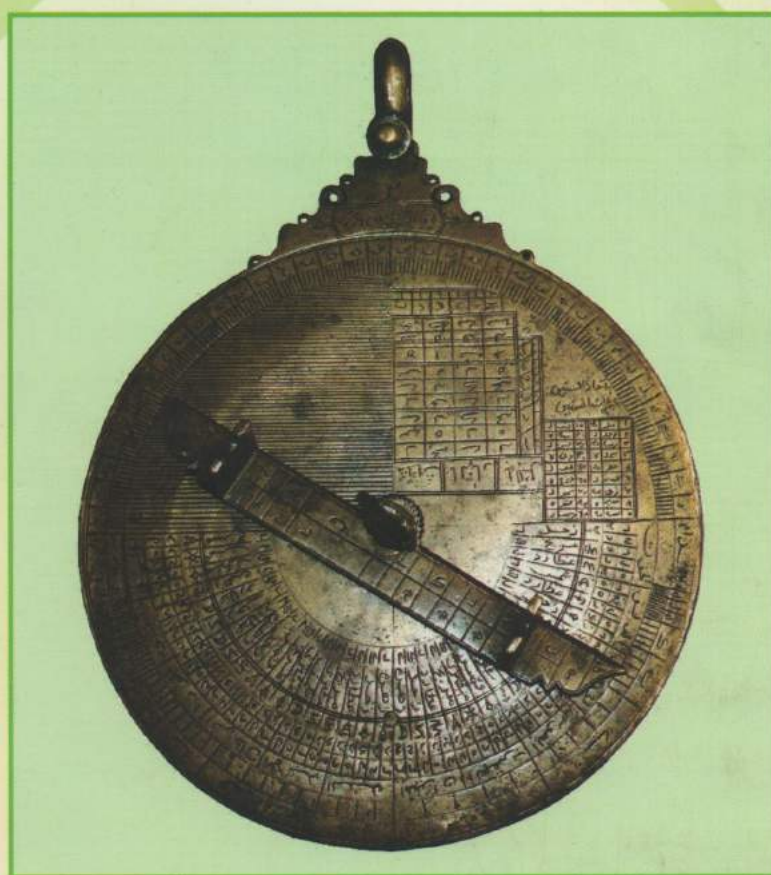
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Back of a Lahore Astrolabe made in 1587 (see pp. 454-477)



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A Lahore Astrolabe of 1587 at Moscow: Enigmas in its Construction

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Abstract

The earliest known dated astrolabe in the Indian subcontinent was made in 1567 by Allāhdād at Lahore. The State Museum of Oriental Art at Moscow owns an astrolabe made twenty years later in 1587 at Lahore. An inscription on the front of this astrolabe states that it is a copy of an astrolabe belonging to Mirzā Bāysunghur. A close examination of the astrolabe shows that there are two different levels in the quality of workmanship. The rete, the alidade and one plate were made by a skilled master. The rest, namely the mater with the geographical gazetteer on the inner side and with the various tables on the back, and four other plates were produced by a person who was not quite familiar with the functions of the astrolabe; these parts do not meet even the minimum requirements of astrolabe construction. This paper provides first a detailed description of the components of the astrolabe and then proceeds to explain the enigmas in its construction. It concludes with a discussion on the possible relationship between the two astrolabes of 1567 and 1587.

Key words: Allāhdād, Greenwich Astrolabe, Lahore, Mirzā Bāysunghur, Moscow Astrolabe, Moscow State Museum of Oriental Art, Ulugh Beg.

1. INTRODUCTION

There are about two thousand planispheric astrolabes in museums and private collections all over the world, which were mostly made between ninth and eighteenth centuries.¹ Each of these is a source of valuable information about the level of scientific knowledge, technology, and artistic preferences at the time of its production. Most astrolabes are preserved in the museums of Great Britain and the United States. Russia made acquaintance with these instruments only in the seventeenth century when everywhere else they were passing out of use. For this reason, the total number of planispheric astrolabes displayed in Russian museums is just 14; on the other hand,

there are many surveying instruments of the 18th–19th centuries, which are traditionally referred to as astrolabes in Russia.

While the museums in St. Petersburg in Russia boast the largest collection of planispheric astrolabes (9 in the State Hermitage, 3 in the Kunstkamera and 1 in the Naval museum), there is only 1 astrolabe in Moscow. It is in the State Museum of Oriental Art and dates back to the sixteenth century. This article is devoted to its study.

This astrolabe was known to be in Astrokhan in 1918; it was acquired by the State Museum of Oriental Art at Moscow in 1939. It was included in the list of scientific instruments drawn

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¹ These are catalogued for the first time by Professor Derek Price and his associates; cf. Gibbs et al (1973).

up by the Soviet historian V. L. Chenakal in 1968 (Chenakal, 1968, p. 43) and in the next year it was described by Smirnov (1969). The *Computerized Checklist of Astrolabes* records it as follows : 996 1587 3674 160 MBK LAHO (Gibbs et al, 1973, p. 29). It means that the year of production is 996 Hijrī, which corresponds to 1587 AD, international number is IC 3674, diameter 160 mm, the place of preservation **MBK** [Moscow Oriental Museum], and place of production Lahore (India, now Pakistan), which city later became a renowned centre for the production of astrolabes.

The earliest known dated astrolabe from Lahore was created by Allāhdād, the founder of a famous dynasty of astrolabe-makers, in 1567,

just 20 years earlier than the object of our study (Sarma, 1996, pp. 7-11, pls. 1-3; Sarma, 2008, p. 204). Therefore, in addition to the description of our astrolabe which will be referred to as “the Moscow astrolabe”, we shall attempt to determine its relation to the work of Allāhdād, and, wherever possible, to reconstruct its history.

2. DESCRIPTION OF THE ASTROLABE

The astrolabe consists of the following standard components: 1. the mater with a “throne” and a suspension ring on its top (Fig. 1); 2. the rete with star pointers (Fig. 2); 3. five plates placed under the rete in the cavity of the mater (Figs. 3, 4); and 4. the alidade with sights (Fig. 13). All the



Fig. 1. The front of the Moscow Astrolabe

parts are held together by a central screw with a slotted nut.

The diameter of the mater is 151 mm² and its thickness 10.8 mm. The diameter of the rete and of the plates is 128 mm. Each of the five plates is 1.2 – 1.3 mm thick. The rete is made of a thicker plate, the thickness of which is 1.7 mm. On the back of the astrolabe, an alidade with two sights is pivoted. The screw and the nut seem to have been added later to the instrument. The total weight of the astrolabe is 1390 gram.

2.1 The Front

On the front of the astrolabe there is an inscription on the throne (Fig. 13):

نقل شد رقوم این اسطرلاب از اسطرلاب حضرت میرزا ابایسنفر نور هری در سنه ۹۹۶ در بنده لاهور
(*naql shud ruqūm ayn ašturlāb az ašturlāb hadrat mīrzā bāysunghur nūr hijrī dar sana 996 dar balda lāhūr*), “The characters (*ruqūm*, literally numbers) of this astrolabe have been copied (*naql*) from the astrolabe belonging to Hazrat Mīrzā Bāysunghur in the year 996 Hijrī in the city of Lahore.”

This date corresponds to 1587-88 AD. As to the name, there were at least three historical figures bearing the name of Bāysunghur in the fifteenth century. The most famous of them, Gīāt al-dīn Bāysunghur (1397–1433), was a grandson of Tamerlane and the youngest son of Shāhrukh Mīrzā. Eventually, he became the mainstay of his father in Herat and was known as a patron of arts and architecture, founder of a library, and a good calligrapher (*Encyclopaedia Iranica*, vol. IV, 1990, pp. 6–9). Bāysunghur’s brother was the astronomer Ulugh Beg who ruled in Samarkand.

The second Bāysunghur, Abul Qāsim Bābur Mīrzā bin Bāysunghur Beg (1422–1457), was the son of the first one and ruled Khurasan

from 1449 to 1457 (Jackson, 1986, pp. 108–112). The third one, Bāysunghur Aq Qoyunlu was also one of Tamerlane’s descendants and ruled from 1490 to 1493. He was dethroned in Samarkand during the wars waged for power by Bābur, the founder of the Mughal dynasty in India. This Bāysunghur was killed in 905 H (1499/1500) (Bakikhanov, 1991).

The rim of the front is graduated for every degree and numbered in groups of 5 degrees in *abjad* numbers, running clockwise, as 5, 10, 15, ... 100, 5, 10, 15, ... 200, 5, 10, 15, ... 300, 5, 10, 15, ... 60.

2.2 The Rete

The rete of this astrolabe is quite simple. It consists of a counter-changed east-west bar, counter-changed meridian and two arcs of the equator circle and the usual ecliptic and Capricorn circles. The ecliptic is divided into the 12 signs of the zodiac; each sign is graduated for every 6°, but not numbered. There are 33 star pointers with the names of the stars engraved on them. On the ecliptic circle at the end of Virgo, there is a knob for rotating the rete.

Some of the star pointers are shaped like long boots, instead of traditional dagger-shape or flame-shape (nos. 2, 7, 9, 14, 16-20, 22, 27 in Fig. 2). The pointer to the star Vega in constellation Lyra is shaped like the beak of a bird. It carries the Arabic name *nasr wāqī*, “the falling eagle”, but on the present rete the eagle has an unexpectedly peaceful appearance and resembles a duck.

The 33 stars are listed below in Table 1; they are identified on the basis of their Arabic names (Kunitzsch & Smart, 2006; Allen, 1899) and by measuring their coordinates.

² Smirnov gives a wrong value of 160 mm and this value is repeated by Gibbs et.al., 1973 p. 29.



Fig. 2. Rete with the star pointers

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Table 1. Stars of the Moscow Astrolabe

| # | Arabic Name as engraved | Transliteration | English translation | Identification | |
|----|-------------------------|-------------------------------|--|----------------------------|-------|
| 1 | كف الخضيب | <i>kaff al-khāḍīb</i> | the stained hand | Caph | β Cas |
| 2 | ذنب قيطس | <i>dhanab qayṭus [janūbī]</i> | the southern tail of Cetus | Deneb Kaitos | β Cet |
| 3 | بطن الحوت | <i>baṭn al-ḥūt</i> | the belly of the fish | Mirach | β And |
| 4 | فم القيطس | <i>fam al-qayṭus</i> | the mouth of Cetus | – | γ Cet |
| 5 | غول | <i>[ra's al-] ghūl</i> | [the head of] the Demon | Algol | β Per |
| 6 | عين الثور | <i>ʿayn al-thawr</i> | the eye of the bull | Aldebaran | α Tau |
| 7 | عيوق | <i>ʿayyūq</i> | (?) | Capella | α Aur |
| 8 | رجل اليسرى | <i>rijl [...] al-yusrā</i> | the left foot [of the hunter] | Rigel | β Ori |
| 9 | مقدم المنطقة | <i>muqaddam al-minṭaqa</i> | first part, beginning of the belt [of the hunter] | Mintaka | δ Ori |
| 10 | يد الجوزا اليمنى | <i>yad al-jawzā' yumnā</i> | the right hand of the hunter | Betelgeuse | α Ori |
| 11 | شعري يمانى | <i>shī'rā yamānī [yyah]</i> | the southern Sirius | Sirius | α CMa |
| 12 | شعري شامي | <i>shī'rā sha'āmī [yyah]</i> | the northern Sirius | Procyon | α CMi |
| 13 | نثرة سحابى | <i>nathra saḥābī</i> | <i>nathra</i> —the tip of the [lion's] nose, <i>saḥābī</i> – a nebulous [star] | Beehive Cluster (Praesepe) | ε Cnc |
| 14 | فرد الشجاع | <i>fard al-shujāʿ</i> | the solitary one of the water snake | Alphard | α Hya |
| 15 | قلب الأسد | <i>qalb al-asad</i> | the lion's heart | Regulus | α Leo |

| | | | | | |
|----|---------------|-----------------------------------|-------------------------------------|----------------|----------------------------|
| 16 | ظهر الأسد | <i>zahr al-asad</i> | the lion's back | Zosma, Dhur | δ Leo |
| 17 | صرفة | <i>şarfa</i> | the changer [of the weather] | Denebola | β Leo |
| 18 | جناح الغراب | <i>janāḥ al-ghurāb</i> | the raven's wing | Gienah | γ Crv |
| 19 | سمك اعزل | <i>simāk [al]-a'zal</i> | the unarmed simāk | Spica | α Vir |
| 20 | العناق | <i>al-^canāq</i> | the badger (a desert animal) | Mizar | ζ UMa |
| 21 | سماك رامي | <i>simāk rāmiḥ</i> | simāk armed with a lance | Arcturus | α Boo |
| 22 | نير الفكة | <i>nayyir al-fakka</i> | the bright one of the broken vessel | Alphecca | α CrB |
| 23 | عنق الحية | <i>ʿunuq al-ḥayya</i> | the serpent's neck | Unukalhai | α Ser |
| 24 | قلب العقرب | <i>qalb al-ʿaqrab</i> | the scorpion's heart | Antares | α Sco |
| 25 | رأس الحوا | <i>ra's al-ḥawwā'</i> | head of the snake-charmer | Rasalhague | α Oph |
| 26 | نسر واقع | <i>nasr [al]-wāqi^c</i> | the swooping eagle | Vega | α Lyr |
| 27 | رأس الجاثي | <i>ra's al-jāthī</i> | head of the kneeling one | Rasalgethi | α Her |
| 28 | منقار الدجاجة | <i>minqār al-dajāja</i> | the hen's beak | Albireo | β Cyg |
| 29 | نسر طائر | <i>nasr ṭā'ir</i> | the flying eagle | Altair | α Aql |
| 30 | ذنب الحوت | <i>dhanab al-ḥūt</i> | tail of the fish ³ | Deneb Algedi | δ Cap |
| 31 | فم الفرس | <i>fam al-faras</i> | the horse's mouth | Enif (Markab) | ε Peg ⁴ (α Peg) |
| 32 | منكب الفرس | <i>mankib al-faras</i> | the horse's shoulder | Scheat | β Peg |
| 33 | ذنب الجدي | <i>dhanab al-jadī</i> | the tail of the goat | Ident. with 30 | δ Cap |

Special measurements were carried out to control the identification, test the accuracy of the rete, and determine the epoch of stellar coordinates. For each pointer, the radius r and mediation m were measured. Then we calculated the equatorial coordinates α and δ of each star by the formulas:

$$\text{tg} [(90^\circ - \delta)/2] = r/r_e, \quad \text{tg} \alpha = \text{tg} m \cdot \cos \varepsilon,$$

where r_e is the radius of the equator, ε is

Table 2. Measurement and calculation of the Stars' positions (degrees)

| | Star | Measur. & calcul. | | | Longitude | | | Latitude | | |
|---|-------|-------------------|-----|----------|-----------|-----------|------------|-----------|-----------|----------|
| | | δ | m | α | Astrolabe | Ulugh Beg | Δ | Astrolabe | Ulugh Beg | Δ |
| 1 | β Cas | 55.9° | 0° | 0° | 30.4° | 28° 1' | 2.4° | 49.4° | 50° 48' | -1.4° |
| 2 | β Cet | -19.4 | 11 | 10.1 | 1.2 | 355 21 | 5.9 | -21.7 | -21 0 | -0.7 |
| 3 | β And | 32.5 | 16 | 14.7 | 26.7 | 23 13 | 3.5 | 24.1 | 25 36 | -1.5 |
| 4 | γ Cet | 1.9 | 38 | 35.6 | 33.9 | 32 10 | 1.7 | -11.6 | -12 18 | 0.7 |
| 5 | β Per | 39.9 | 42 | 39.5 | 49.9 | 48 55 | 1.0 | 23.2 | 22 | 1.2 |
| 6 | α Tau | 18.9 | 66 | 64.1 | 65.6 | 62 31 | 3.1 | -2.4 | -5 15 | 2.8 |
| 7 | α Aur | 44.5 | 75 | 73.7 | 77.6 | 74 43 | 2.9 | 21.8 | 22 42 | -0.9 |

³ (#30) apparently, in this case the fish is Capricornus.

⁴ Pointer #31 corresponds to α Peg by coordinates, but by name it is ε Peg.

the obliquity of the ecliptic (23°30'). The next step was to calculate ecliptic coordinates – longitude and latitude – and compare the obtained values with those prevalent the in 15th-16th centuries in the *Zij-i Jadīd-i Sultāni (Zij-i Gurganī)*. This *Zij* is often referred to as *Zij-i Mīrzā Ulugh Bīk*, as it was compiled in 1437 by Samarqand astronomers supervised by Ulugh Beg (1394–1449) (Kennedy, 1956, pp. 3-4, pp. 44–45). (Table 2.)

| | | | | | | | | | | |
|----|-------|-------|-----|-------|-------|--------|-------------|-------|--------|------------|
| 8 | β Ori | -10.0 | 75 | 73.7 | 70.9 | 69 25 | 1.5 | -32.4 | -31 18 | -1.1 |
| 9 | δ Ori | -1.0 | 77 | 75.9 | 74.6 | 74 34 | 0 | -23.7 | -23 57 | 0.2 |
| 10 | α Ori | 6.3 | 84 | 83.5 | 83.2 | 81 13 | 2.0 | -17 | -16 45 | 0.2 |
| 11 | α CMa | -17.0 | 96 | 96.5 | 98.1 | 96 19 | 1.8 | -40.3 | -39 30 | -0.8 |
| 12 | α CMi | 5.8 | 107 | 108.4 | 109.1 | 108 22 | 0.7 | -16.4 | -16 0 | -0.4 |
| 13 | ε Cnc | 20.5 | 122 | 124.3 | 121.9 | 119 46 | 2.1 | 0.8 | 1 0 | 0.2 |
| 14 | α Hya | -4.0 | 135 | 137.5 | 141.2 | 139 31 | 1.7 | -19.4 | -22 30 | 3.1 |
| 15 | α Leo | 13.9 | 142 | 143.0 | 140.8 | 142 13 | -1.4 | -0.7 | 0 9 | -0.9 |
| 16 | δ Leo | 20.5 | 160 | 160.5 | 154.2 | 153 28 | 0.7 | 11.4 | 14 9 | -2.7 |
| 17 | β Leo | 15.7 | 170 | 170.7 | 165.2 | 163 49 | 1.4 | 10.7 | 12 0 | -1.3 |
| 18 | γ Crv | -13.4 | 180 | 180 | 185.4 | 182 46 | 2.6 | -12.3 | -14 18 | 2.0 |
| 19 | α Vir | -9.0 | 197 | 196 | 198.2 | 196 10 | 2.0 | -2 | -2 9 | 0.1 |
| 20 | ζ UMa | 57.6 | 198 | 197.3 | 159 | 158 4 | 0.9 | 56.9 | 56 12 | 0.7 |
| 21 | α Boo | 21.1 | 210 | 208 | 197.4 | 196 31 | 0.9 | 30.3 | 31 18 | -1.0 |
| 22 | α CrB | 29.7 | 232 | 229.6 | 216.0 | 214 34 | 1.4 | 45.9 | 44 30 | 1.4 |
| 23 | α Ser | 10.0 | 236 | 233.7 | 228.5 | 224 25 | 4.1 | 28.4 | 25 48 | 2.6 |
| 24 | α Sco | -25.1 | 244 | 242 | 244.8 | 240 28 | 4.3 | -4.1 | -3 45 | -0.3 |
| 25 | α Oph | 12.8 | 261 | 260.2 | 258.2 | 255 13 | 3.0 | 35.8 | 35 51 | -0.1 |
| 26 | α Lyr | 37.6 | 274 | 274.4 | 277.2 | 278 19 | -1.1 | 60.9 | 62 | -1.1 |
| 27 | α Her | 15.1 | 275 | 275.5 | 276.8 | 247 55 | 28.9 | 38.4 | 37 30 | 0.9 |
| 28 | β Cyg | 27.0 | 287 | 288.4 | 295.3 | 294 25 | 0.9 | 48.8 | 49 12 | -0.4 |
| 29 | α Aql | 9.0 | 291 | 292.7 | 296.2 | 294 10 | 2.0 | 30.4 | 29 15 | 1.1 |
| 30 | δ Cap | -16.8 | 320 | 322 | 319 | 315 28 | 3.5 | -1.8 | -2 15 | 0.4 |
| 31 | α Peg | 13.9 | 340 | 340.5 | 347.6 | 345 55 | 1.7 | 20.4 | 19 0 | 1.4 |
| 32 | β Peg | 25.0 | 340 | 340.5 | 352.7 | 351 37 | 1.1 | 30.5 | 30 51 | -0.3 |
| 33 | δ Cap | -16.8 | 350 | 350.7 | 344.8 | 314 13 | 30.6 | -11.8 | -2 30 | 9.3 |

The performed calculations suggest the following conclusions:

1. The manufacturing precision of the pointers is rather high; for the latitude it is about 1.1 degrees, which shows the work of an experienced maker.
2. Due to precession, longitudes of stars in the astrolabe are higher than Ulugh Beg’s longitudes on average by 1.4 degrees. At that time, as a rule, permanent precession of 1 degree per 66 years was normally used, so the epoch of the astrolabe stars is about a hundred years later than Ulugh Beg’s *zīj* (1437). This date – about **1537** – is beyond the life span of all the Bāysunghurs. The source of the star coordinates might have been some *zīj* of this period based on Ulugh Beg’s catalogue (but not necessarily so).

3. For stars no. 27 and 33, error in longitude is about 30 degrees, which indicates a possible error in the sign of the zodiac. This mistake was committed either by the author of the original *zīj* or by the maker.

The rete of the Moscow astrolabe will be compared with the retes of other astrolabes made in Lahore over the same period in the last part of this article.

2.3 The Plates

In the cavity of the mater, there are five plates. All the plates have a small hole in the lower part of the meridian line, into which fits the knob protruding in the same position on the inner side of the mater. Both the sides of each plate are engraved with altitude circles, azimuth arcs and hour lines as shown in Table 3. The two sides of each plate are designated by letters “a” and “b”.

Table 3. Plates and their sides

| Sides | Latitude | Maximum Day length on the plate | | Maximum Day length in theory ⁵ | |
|-------|----------|---------------------------------|------------|---|------------|
| Ia | 21°40' | 14 | hrs 20 min | 13 | hrs 20 min |
| Ib | Horizons | | | | |
| IIa | 12° | 14 | 36 | 12 | 43 |
| IIb | 32° | 14 | 17 | 14 | 07 |
| IIIa | 30° | 13 | 58 | 13 | 57 |
| IIIb | 46° | 14 | 40 | 15 | 35 |
| IVa | 36° | 14 | 30 | 14 | 28 |
| IVb | 54° | 15 | 20 | 16 | 55 |
| Va | 42° | 14 | 58 | 15 | 05 |
| Vb | 50° | 14 | 58 | 16 | 11 |

The obverse side of the first plate (Fig. 3) is engraved for the latitude of Mecca. The altitude circles are drawn for every 6° and numbered in *abjad* notation on both sides of the meridian. The curves of azimuths are drawn below the horizon line for every 10° and numbered. There are plain lines for unequal hours and dotted lines for the equal hours which are also numbered. In the middle of the plate is engraved *makka al-^card 21 40* (Mecca, the latitude of 21°40') and *sā'āt 14 20* (the hours of the longest day 14 hrs 20 min). The second value is wrong. It should be 13 hrs 20 min.



Fig. 3. Plate Ia for Mecca
© The State Museum of Oriental Art, Moscow

The reverse side (Fig. 4) is engraved with four sets of half horizons. These horizons allow one to make certain astronomical calculations for places at different latitudes, even for those latitudes for which there is no separate plate in the astrolabe. This plate is convenient for compiling tables. Such a plate was first introduced by Ḥabash al-Ḥāsib in the ninth century and later it became a standard component under the name *ṣafīḥa āfāqī* (Morrison, 2007, p. 64).



Fig. 4. Plate Ib with multiple horizons
© The State Museum of Oriental Art, Moscow

In the present plate, there are four sets of half-horizons for latitudes between 4° and 66°, arranged at intervals of 8 degrees in the following manner:

| | | | | | | | |
|----|----|----|----|----|----|----|----|
| 4 | 12 | 20 | 28 | 36 | 44 | 52 | 60 |
| 6 | 14 | 22 | 30 | 38 | 46 | 54 | 62 |
| 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 |
| 10 | 18 | 26 | 34 | 42 | 50 | 58 | 66 |

In addition, there is an extra half-horizon in each of the four quadrants, accompanied by labels as shown below.

⁵ King (2005): 931. Day length values calculated with $\epsilon = 23^\circ 35'$.

1. Half-horizon for 66;30°; below it is engraved أفق عرض سول ساعاته (*ufq^c arḍ 66;30 sā'āt*), “horizon of the latitude 66;30°; hours [of the longest day at this latitude]”. The label does not mention the hours; they should be 24.
2. Half-horizon for 72°; below it is engraved أفق عرض عب اليوم فيه عب (*ufq^c arḍ 72 al-yawm fī 72*), “horizon of the latitude 72°; the day is 72”.
3. Half-horizon for 78°; below it is engraved أفق عرض عب اليوم فيه قيد (*ufq^c arḍ 78 al-yawm fī 114*), “horizon of the latitude 78°; the day is 114”.
4. Half-horizon for 84°; below it is engraved أفق عرض فد اليوم فيه قمو (*ufq^c arḍ 84 al-yawm fī 146*), “horizon of the latitude 84°; the day is 146”.

An astrolabe made by Yusuf ibn Hājī al-Jīlānī in 1522 [now at the National Maritime Museum, Greenwich (Charette, 2005, p. 222)], which will be discussed below, has a similar horizon plate, with these four extra half-horizons with almost the same labels. In his description of this astrolabe, François Charette explains the labels as follows: “We should understand the expression ‘the day is ...’ as meaning ‘the number of days in a year with a 24-hour daylight is ...’.”

Accordingly, at latitude 72°, there are 72 days in a year with a 24-hours daylight; at latitude

78°, there are 114 days in a year with a 24-hours daylight; and at latitude 84°, there are 146 days in a year with a 24-hours daylight, [and at latitude 90°, there are 180 days in a year with a 24-hours daylight]. But these figures are not very accurate. The correct figures are given in the following table 4.

Furthermore, there are three more inscriptions outside the circle of equator (which are not found on the astrolabe of 1522):

5. Below the half-horizon for latitude 84° is written يطلع ستة بروج على الدفعة و ستة على التدرج (*yaṭla^c sitta burūj^c alī al-duf^c a wa sitta^c alī al-tadrīj*), “six [zodiacal] signs rise simultaneously and [the other] six [signs] gradually”.
6. Below the half-horizon for latitude 78° is written يطلع الثور قبل الحمل معكوسا (*yaṭla^c al-thawr qabl al-ḥamal ma^c kūṣā*), “Taurus rises before Aries inversely”.
7. Below the half-horizon for latitude 72° is written يطلع القمر [الحمل؟] قبل الحوت معكوسا (*yaṭla^c al-qamar [al-ḥamal] qabl al-ḥūt ma^c kūṣā*), “the moon [Aries?] rises before Pisces inversely”.

These statements are highly intriguing and rather incomprehensible. At latitude 84°, the six signs ascend from Aries to Virgo. What is stated in 6 and 7 with regard to the latitudes 72° and 78° is not clear. The correct position is shown in the table 5. below.

Table 4. Occurrence of 24-hours daylight at higher latitudes

| Latitude | Declination of the Sun (minimum) | Occurrence of 24-hours daylight | Number of days with 24-hours daylight in theory | Number of days mentioned on the horizon plate |
|----------|----------------------------------|---------------------------------|---|---|
| 66°30' | +23°30' | 22 June only | 1 | – |
| 72° | +18° | 12 May– 2 August | 82 | 72 |
| 78° | +12° | 22 April– 22 August | 122 | 114 |
| 84° | +6° | 5 April – 8 September | 156 | 146 |

Table 5. Risings of the Signs at higher latitudes

| | Longitude | Declination | Latitude 72 | Latitude 78 | Latitude 84 |
|-------------|-----------|-------------|--------------|--------------|--------------|
| Aries | 0 | 0 | rises | rises | rises |
| Taurus | 30 | +11 30 | rises | rises | rises |
| Gemini | 60 | +20 10 | rises | rises | rises |
| Cancer | 90 | +23 30 | rises | rises | rises |
| Leo | 120 | +20 10 | rises | rises | rises |
| Virgo | 150 | +11 30 | rises | rises | rises |
| Libra | 180 | 0 | rises | rises | partly rises |
| Scorpio | 210 | -11 30 | partly rises | partly rises | never rises |
| Sagittarius | 240 | -20 10 | never rises | never rises | never rises |
| Capricorn | 270 | -23 30 | never rises | never rises | never rises |
| Aquarius | 300 | -20 10 | partly rises | partly rises | never rises |
| Pisces | 330 | -11 30 | rises | rises | partly rises |

There are also four sets of declination scales along the four radii inside and outside the circle of equator, divided in 1° and 3° and numbered from 3 to 24 with the labels *mayl shamālī* (northern declination) inside the equator and *mayl janūbī* (southern declination) outside the equator.

While plate I was made reasonably correctly, the remaining four plates are absolutely non-functional. They were made without compliance with the rules, “by eye,” as the saying goes. The centres of the altitude circles are

positioned inaccurately. The latitudes mentioned on the plates do not match the locations of the centres, the circles are inscribed incorrectly, the maximum duration of the day does not match the latitude, and so on. The maker of the plates seems to have been ignorant about the rules of this work. Obviously, the first plate is strikingly different from the rest of them. It was made by an experienced astrolabist and demonstrates strict adherence to all canons (except for the wrong length of the day).

**Fig. 5.** Plate IVb and Plate IIa

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Two examples will suffice to show the incompetence of the maker of the remaining plates. On plate IVb, which is on the left in Fig. 5, the horizon touches the Capricorn circle. This is possible only at latitude 67° and not at latitude 54° for which the plate is said to have been designed. On plate IIa, which is on the right in Fig. 5, all the altitude circles are drawn from the same centre which is at the zenith. This violates the rules of stereographic projection. Moreover, the zenith is placed on the Cancer circle. This corresponds to latitude 23° , and not to 12° as written on the plate.

2.4 The Geographical Gazetteer

A geographical gazetteer with the names, longitudes, latitudes and *qibla* of 84 places is engraved on the inner surface of the mater. The numbers are inscribed in the Persian version of *abjad* notation; the notation of some figures is different from the classical inscriptions, for instance, number 20 is ڪ instead of ك. There are zero digits in the gazetteers, which are indicated by a sign resembling an inverted letter “*ayn*”. This sign is not found on other 16th-century astrolabes.

The longitudes of cities were counted, according to the tradition dating back to Ptolemy, from the mythical Isles of Fortune situated around 35–36 degrees to the west of the Greenwich meridian. For example, the longitude of the Iranian city of Isfahan is $51^\circ 29'$. The astrolabe shows the value of $86^\circ 40'$, the difference is $35^\circ 11'$. *Qibla*, the direction that should be faced when a Muslim prays, which is fixed as the direction of the Kaaba in Mecca, was not given for all cities; it was engraved only wherever there was space.

On the left half of the mater between the rows of the coordinates, the engraver, for no apparent reason, copied the inscription from the front of the throne once again (it is encircled by us in white colour in Fig. 7):

در ۹۹۶ هری مرقوم شد نقل از اسطرلاب بایسنغر (*dar 996 hijrī marqūm shud naql az ašturlāb bāysunghur*), “in the year 996 Hijrī the copy was inscribed from the astrolabe of Bāysunghur”.

There ought to have been three circles, each consisting of four rows to accommodate the place names, longitudes, latitudes and *qibla* respectively. This gazetteer violated the symmetry and broke the circular arrangement of the rows on the left and right sides (see Fig. 6). No such distortion can be seen on any other Arabic astrolabe!

The argument (*buldān* = cities; *ṭūl* = longitude; *‘ard* = latitude; *inḥirāf* = the angle of orientation towards Mecca, or *qibla*) is engraved, correctly, on the left at the top (encircled in red). This should have been followed immediately by Mecca and its coordinates, but these were engraved below the argument. Four localities are duplicated (Balkh, nos. 46 and 74; Kājerūn, nos. 53 and 82; Khujand, nos. 47 and 77; Aden, nos. 36 and 67), so that there are actually 83 cities in the table, out of which only 26 have a *qibla*.

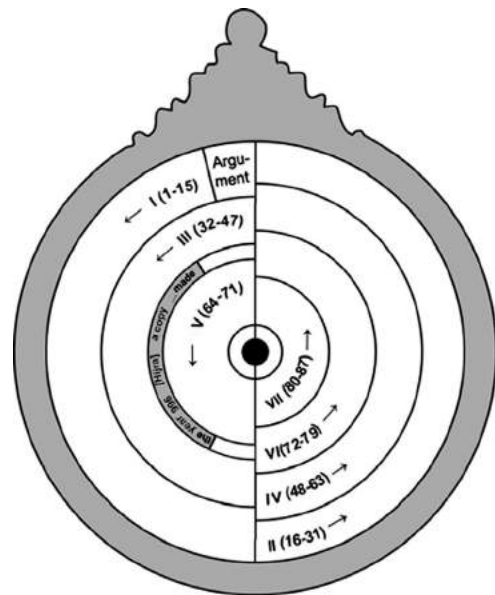


Fig. 6. Diagram showing the dislocation of the circular rows in the gazetteer

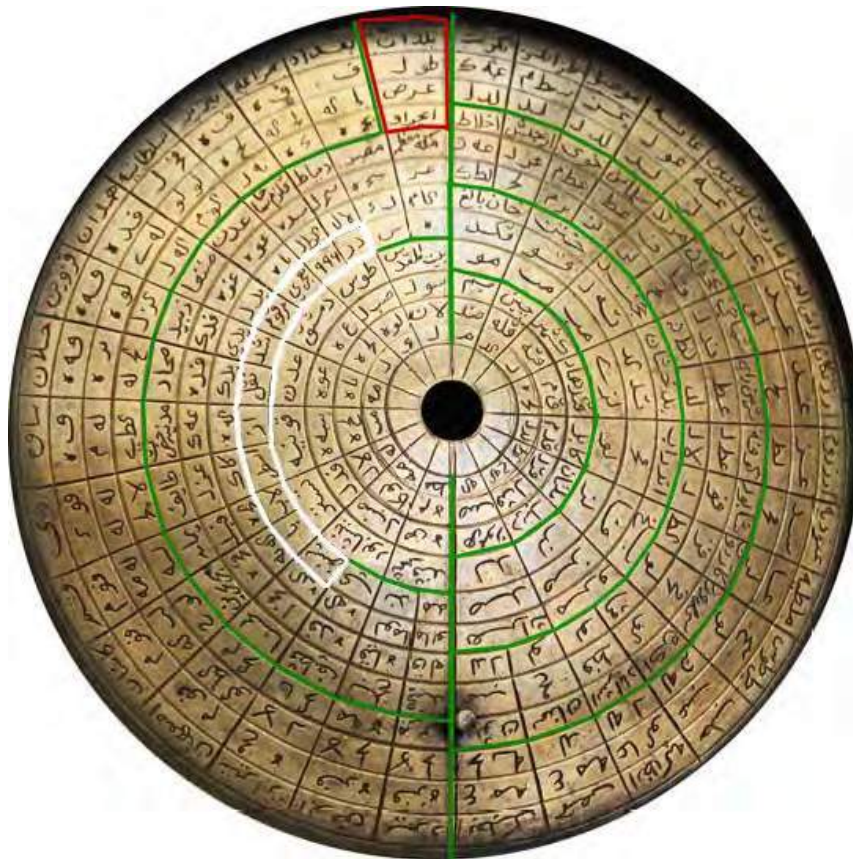


Fig. 7. The geographical gazetteer (coloured lines are added by us)
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Table 6. The geographical gazetteer⁶

| | Place Name | | Longitude | Latitude | <i>Inḥirāf</i> |
|--------------|---------------|---------|-----------|----------|----------------|
| Row I | | | | | |
| 1 | Baghdād | بغداد | 80°0' | 33°25' | 13°0' |
| 2 | Marāgha | مراغه | 82 0 | 37 20 | 15 50 |
| 3 | Tabrīz | تبریز | 82 0 | 38 0 | 15 30 |
| 4 | Sultāniya | سلطانيه | 83 30 | 36 36 | 26 40 |
| 5 | Hamadān | همدان | 84 0 | 35 10 | 25 30 |
| 6 | Qazwīn | قزوین | 85 0 | 36 0 | 27 30 |
| 7 | Jilān (Gilan) | جلان | 85 | 37 0 | 28 35 |
| 8 | Sāwa | ساوه | 85 0 | 35 0 | [39] 57 |
| 9 | Rayy (Tehran) | ری | 86 20 | 35 35 | 31 33 |
| 10 | Qum | قم | 86 40 | [35] 45 | 35 |
| 11 | Kāshān | کاشان | 86 40 | [32] 25 | 36 8 |

⁶ Names of localities in square brackets are doubtful. Numbers in square brackets are incorrect values of coordinates. Cf. Gibbs & Saliba (1984):192–200.

| | | | | | |
|----------------|--------------------------|-----------|--------|---------|-------|
| 12 | Işfahān | اصفهان | 86 40 | [29] 26 | 40 23 |
| 13 | Shīrāz | شیراز | 88 0 | 31 30 | 51 23 |
| 14 | Abarqūh | ابرقوه | 84 0 | 31 13 | 45 0 |
| 15 | Yazd | یزد | 87 0 | 31 13 | 47 17 |
| Row II | | | | | |
| 16 | Ba ^o albek | بعلبک | 70 45 | 33 15 | |
| 17 | Hims (Homs) | حمص | 70 45 | 34 | |
| 18 | Antākya | انطاکیه | 71 26 | 35 30 | |
| 19 | Ḥalab (Aleppo) | حلب | 72 | 35 50 | |
| 20 | Tartūs | طرطوس | 68 | 36 | |
| 21 | Malatīya | مطیبه | 71 | 37 | |
| 22 | Ammūriya | اموریه | 64 | 43 | |
| 23 | Erzurūm | ارزروم | 77 | 39 | |
| 24 | Erzincān | ارزنکان | 74 | 38 | |
| 25 | Rās al- ^o Ayn | راس العین | 74 | 36 | |
| 26 | Mārdīn | ماردین | 74 | 37 | |
| 27 | Nuṣāybin | نصابین | 75 | 37 | |
| 28 | Āna | عانه | 76 30 | 34 | |
| 29 | Mūṣil (Mosul) | موصل | 77 | 34 30 | |
| 30 | Ṭarābulus (Tripoli) | طرابلس | 69 40 | 34 | |
| 31 | Tikrīt | تکریت | 75 20 | 34 30 | |
| Row III | | | | | |
| 32 | Makka Mukarramah (Mecca) | مکه مکرمه | 77 | 21 40 | |
| 33 | Miṣr (Egypt) | مصر | 63 0 | 30 20 | |
| 34 | Damietta | دمياط | 63 30 | 31 30 | |
| 35 | Qulzum Sāḥā | قلزم ساحا | 64 0 | 29 30 | |
| 36 | Ādan (Aden) | عدن | 76 0 | 11 0 | |
| 37 | Ṣana ^o ā | صنعا | 76 0 | 14 30 | |
| 38 | Zabīd | زبید | 84 20 | 14 10 | |
| 39 | Ṣuḥār | صحار | 84 0 | 14 20 | |
| 40 | Madīna (Medina) | مدینة | 75 20 | 25 0 | |
| 41 | Ṭāyif | طایف | 77 30 | 21 20 | |
| 42 | Yamāma | یمامة | 82 30 | 23 0 | |
| 43 | Jaḥīn | جحن | 83 0 | 25 15 | |
| 44 | Laḥsā | لحسا | 83 30 | 24 0 | |
| 45 | Qatīf | قطیف | 84 0 | 25 0 | 20 |
| 46 | Balkh | بلخ | 101 | 36 41 | 54 |
| 47 | Khujand | خجند | 100 35 | 41 36 | 45 |
| Row IV | | | | | |
| 48 | Tūn | تون | 92 | 34 30 | |
| 49 | Samnān | سمنان | 83 | 36 | |

| | | | | | |
|----------------|----------------------|------------|--------|-------|----|
| 50 | Astarābād | استرآباد | 89 | 36 | |
| 51 | [qut] (Quwait ?) | اقت | 82 | 26 | |
| 52 | [Sūfard] | سوفرد (?) | 88 | 36 | |
| 53 | Kāzirūn | کازرون | 87 | 29 | |
| 54 | Shābūr | شاپور | 86 | 30 | |
| 55 | Kūfa | کوفه | 79 30 | 31 30 | |
| 56 | Sāmarrā | سامراء (?) | 79 | 34 | |
| 57 | Shamākhī | شماخي | 84 30 | 39 50 | |
| 58 | Nakhjiwān | نخجوان | 81 | 38 | |
| 59 | Marand | مرند | 80 | 37 | |
| 60 | Salamās | سلماس | 79 | 37 | |
| 61 | Khoy | خوی | 79 40 | 37 40 | |
| 62 | [Arjāshan] | ارجاشن | 77 30 | 38 | |
| 63 | Akhlāt | اخلاط | 75 50 | 39 20 | |
| Row V | | | | | |
| 64 | Bayt al-Maqdis | بيت المقدس | 66 30 | 31 50 | 30 |
| 65 | Tūs | طوس | 92 30 | 36 | 45 |
| 66 | Dimashq | دمشق | 70 0 | 33 0 | 30 |
| 67 | °Adan (Aden) | عدن | 76 | 11 | 45 |
| 68 | Konya | قونیه | 69 0 | 38 0 | 42 |
| 69 | Shustar | شستر | 84 30 | 31 30 | 35 |
| 70 | Nīshābūr | نیشاپور | 82 30 | 36 21 | 45 |
| 71 | Samarqand | سمرقند | 90 | 40 0 | 49 |
| Row VI | | | | | |
| 72 | Herāt | هرات | 94 | 30 30 | |
| 73 | Marw | مرو | 97 | 37 | |
| 74 | Balkh | بلخ | 101 | 37 | |
| 75 | Andarāb | اندراب | 83 | 36 | |
| 76 | Badakhshān | بدخشان | 104 24 | 34 10 | |
| 77 | Khujand | خجند | 105 30 | 42 | |
| 78 | Khutan | ختن | 86 | 42 | |
| 79 | Khānbāligh (Beijing) | خانبالغ | 124 | 46 | |
| Row VII | | | | | |
| 80 | Hurmūz (Ormuz) | هرموز | 92 | 25 | |
| 81 | Daibal | دیبیل | 82 30 | 25 20 | |
| 82 | Qājirān | قازران | 87 30 | 29 | |
| 83 | Kābul | کابل | 104 40 | 34 30 | |
| 84 | Qandahār | قندهار | 100 40 | 33 | |
| 85 | Kashmir | کشمیر | 105 | 30 | |
| 86 | Chīn (China) | چین | 135 | 24 | |
| 87 | [?] | ما (?) | 92 30 | 40 | |

It is interesting to look at the geographical distribution of these localities, which shows the main trade routes much before the Safavid Empire.

In this gazetteer, there are no western cities of the Maghreb countries, no Indian cities, and, there is no Lahore.



Fig. 8. Distribution of cities featured in the gazetteer. The first 15 cities are highlighted in red. Two easternmost Chinese cities (nos. 79 and 86), which somehow happen to be in the list, are not shown here.

2.5 The Back of the Astrolabe

On the reverse side (back) of the astrolabe there is an inscription on the throne which reads *إصاحبه السعادة والسلامة*, (*l'sāḥab al-sa'āda wa al-^callāma*), “may happiness and peace be with the owner of this [astrolabe]”.

On the upper half of the rim are engraved the altitude scales divided in 1° and 5° . These are numbered separately on the left and right from 5 to 90.

In the upper left quadrant there is a Sine scale. It usually consists of 60 horizontal lines. In our case, there are more lines than necessary, namely 67. This scale can be used with the help of the alidade (see Fig. 9).

In the upper-right quadrant, it is customary to draw the declination arcs. Instead there is a pitiful hint of a shadow square, which is usually

placed in the lower half of the back. The scales are broken and not functional because they are drawn incorrectly. In addition, two astrological tables are inserted here.

The first is **the table of triplicities** and their day and night ruling planets. In this scheme, the 12 signs of the zodiac are grouped into 4 sets of 3 signs each, so that in each set, the signs are 120° apart. The signs are ruled by different planetary rulers in the daytime and at night. The scheme follows the tradition of the first century astrologer Dorotheus of Sidon who wrote an instructional poem on astrology in Greek in five books. There are similar tables on several Arab astrolabes from the Museum of Greenwich (Ackermann, 2005, pp. 80-81) and also on the Lahore astrolabes (Kaye, 1918, pp. 119-126). When the table of triplicities is engraved on the astrolabe, the signs are represented by their serial numbers in *abjad*



Fig. 9. The back of the astrolabe
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notation from 0 to 11 and the planets by the last letter of their Arabic name. The four sets are



Fig. 10. Table of Triplicities engraved upside down (on the right there is a fragment of the shadow square with numbers 2, 4, 6, 8, 10, 12). Detail of Fig. 9.

assigned to the four elements: Aries, Leo and Sagittarius (0, 4, 8) to the “fire”; Taurus, Virgo and Capricorn (1, 5, 9) to the “earth”; Gemini, Libra and Aquarius (2, 6, 10) to the “air”; Cancer, Scorpio and Pisces (3, 7, 11) to the “water”.

The astrolabe maker engraved the table upside-down as shown in Fig. 10. The row containing the argument is at the bottom. It reads *muthallathāt* (triplicities), *bi al-nahār* (in the day) and *bi al-layal* (at night). Actually the argument should have been in a column on the right of the table. Moreover, in the table the triplicities should have been shown first and not the planetary rulers of the day.

We reproduce below the table of triplicities after rearranging it properly.

Table 7. Triplicities

| | | | | |
|-------------------------|---------------|-------------|-------------|-----------|
| The triplicities | 0 Aries | 1 Taurus | 2 Gemini | 3 Cancer |
| | 4 Leo | 5 Virgo | 6 Libra | 7 Scorpio |
| | 8 Sagittarius | 9 Capricorn | 10 Aquarius | 11 Pisces |
| Ruling planets by day | س Sun | ♀ Venus | ♄ Saturn | ♀ Venus |
| | ♃ Jupiter | ☾ Moon | ☿ Mercury | ♂ Mars |
| | ♄ Saturn | ♂ Mars | ♃ Jupiter | ☾ Moon |
| Ruling planets at night | ♃ Jupiter | ☾ Moon | ☿ Mercury | ♂ Mars |
| | س Sun | ♀ Venus | ♄ Saturn | ♀ Venus |
| | ♄ Saturn | ♂ Mars | ♃ Jupiter | ☾ Moon |

The second table engraved on the upper right quadrant is usually designated as *faḍl al-dawr* (excess of revolution); it is a kind of **Calendar Table**. Unlike the previous table, this one is correctly placed. It shows the excess of the duration of the average year over the integer number of days. For example, one tropical year exceeds the integer number of days 365 by 5 hours 48 minutes 59 seconds. This excess corresponds to 87 degrees 15 minutes. The table shows the multiples of this value, from 1 to 90. In the first column on the right are the numbers 1 to 9 in common Arabic/Persian numerals; in the second and third columns are the multiples of excess in degrees and minutes respectively. Again in the fourth column are the decades 10 to 90 and in the next two columns, the corresponding multiples of the excess. There is a similar table, for example, on a Persian astrolabe made by a representative of Kirmānī family two centuries earlier, in 1388 (Pingree, 2009, pp. 42–47). This table can also be found on many Lahore astrolabes.

Above the table are two lines of writing. It is not the name of the table, but the argument. The first line reads *أحاد اسلین* (*āḥād aslīn*), “units of years”; this should have been written in the table above the first three columns on the right where the multiples are in units. The second line reads *عشر داث اسلین* (*ashar dāth aslīn*), “tens of years”: this should have been written in the table above the fourth, fifth and sixth columns where the multiples

are in tens.

We believe that the purpose of this table may be as follows. It could be intended for the calculation of the so-called “solar returns” in casting the annual horoscope of the “native”. Such a horoscope was cast for the moment when the sun returned to the same position on the ecliptic where it was at the birth of “native”. At that time, the “stakes” of the birth horoscope - the so-called “upper mid-heaven” and the “lower mid-heaven” (i.e., the two intersections of the ecliptic and the meridian) - will be displaced by the amount of the excess. The values of the table cover the man’s possible life span from 1 to 99 years. The calculation procedure was described, for instance, by al-Khwārizmī in the 33rd chapter



Fig. 11. The Calendar Table (detail of Fig. 9)

of the “Treatise on using an astrolabe” more than a thousand years ago.⁷

Table 8. Excess of Revolution

| Minutes | Degrees | Tens of years | Minutes | Degrees | Units of years |
|---------|---------|---------------|---------|---------|----------------|
| 30 | 152 | 10 | 15 | 87 | 1 |
| 0 | 305 | 20 | 30 | 174 | 2 |
| 30 | 97 | 30 | 45 | 261 | 3 |
| 0 | 250 | 40 | 0 | 349 | 4 |
| 30 | 42 | 50 | 15 | 76 | 5 |
| 0 | 195 | 60 | 30 | 163 | 6 |
| 30 | 347 | 70 | 45 | 250 | 7 |
| 0 | 140 | 80 | 0 | 338 | 8 |
| 30 | 292 | 90 | 15 | 65 | 9 |

Let us now consider scales in the lower half of the back. For convenience, they are numbered from the outer periphery upto the centre by Roman numerals from I to VIII.

In the lower part on the edge of the limb, there are two **Cotangent scales**. The inscription on the left says *al-aṣābi*, i.e. “fingers” and on the right “*al-aqdām*”, i.e. “feet”. The values of the function are to be taken in a duodecimal system on the left and in a septenary system on the right. For instance, $\text{ctg } 60^\circ = 0.577$ (decimal system) = $7/12$ (duodecimal) = $4/7$ (septenary). The scale on the left reading is not 7, as it should be, but about 7.7. The scale on the right reading is not 4, as it should be, but 5. This implies the low accuracy of the scales.

The Zodiacal scale (scale III) containing the names of the 12 signs, starts on the left side and proceeds counter-clockwise.

The Terms (scales IV and V) show the division of each sign of the zodiac into five unequal parts. The Ruling planets are designated by the last letter of their Arabic name, as in the



- VIII – auxiliary numbers
- VII – Indian Decans
- VI – Decan rulers
- V – Length of Terms
- IV – Term rulers
- III – Zodiac signs
- II – Cotangent scale divisions
- I – Cotangent scales

Fig. 12. Scales on the lower half of the back (detail of Fig.9)

⁷ al-Khwārizmī (1983): 263. Al-Khwārizmī used an excess equal to 93 degrees, which corresponds to the sidereal year, the time taken by the Earth to orbit the Sun once with respect to the fixed zodiac sign (without precession).

table of triplicities. The method for division that we find here goes back to Ptolemy’s Tetrabiblos. Ptolemy himself called this method Egyptian since it dates back to Nechepsos and Petrosiris (151 BC). There are several instruments with such scales in the collection of the Greenwich museum. (Ackermann, 2005, pp.79-80) This table also occurs in many Lahore astrolabes.

Table 9. The scale of Terms. Correct values are given in square brackets.

| Zodiac sign | Ruling planet (scale IV) | Term length (scale V) |
|-------------|--------------------------|-----------------------|
| Aries | Jupiter | 6 |
| | Venus | 6 |
| | Mercury | 8 |
| | Mars | 5 |
| | Saturn | 5 |
| Taurus | Venus | 8 |
| | Mercury | 6 |
| | Jupiter | 8 |
| | Saturn | 5 |
| | Mars | 3 |
| Gemini | Mercury | 6 |
| | Jupiter | 6 |
| | Venus | 5 |
| | Mars | 7 |
| Cancer | Saturn | 6 |
| | Mars | 7 |
| | Venus | 7 [6] |
| | Mercury | 6 |
| | Jupiter | 6 [7] |
| Leo | Saturn | 7 [4] |
| | Jupiter | 4 [6] |
| | Venus | 6 [5] |
| | Saturn | 5 [7] |
| | Mercury | 7 [6] |
| Virgo | Mars | 6 |
| | Mercury | 7 |
| | Venus | 10 |
| | Jupiter | 8 [4] |
| | Saturn | 4 [2] |

| | | |
|-------------|---------|-------|
| Libra | Saturn | 6 |
| | Mercury | 8 |
| | Jupiter | 7 |
| | Venus | 7 |
| | Mars | 2 |
| Scorpio | Mars | 7 |
| | Venus | 4 |
| | Mercury | 8 |
| | Jupiter | 5 |
| Sagittarius | Saturn | 6 |
| | Jupiter | 12 |
| | Venus | 5 |
| | Mercury | 4 |
| | Saturn | 4 [5] |
| Capricorn | Mars | 4 |
| | Mercury | 7 |
| | Jupiter | 7 |
| | Venus | 8 |
| Aquarius | Saturn | 4 |
| | Mars | 4 |
| | Mercury | 7 |
| | Venus | 6 |
| | Jupiter | 7 |
| Pisces | Mars | 5 |
| | Saturn | 5 |
| | Venus | 12 |
| | Jupiter | 4 |
| Pisces | Mercury | 3 |
| | Mars | 4 [9] |
| | Saturn | 2 |

The Faces (or Decans). This division of each sign of the zodiac into three equal parts of 10 degrees is of Chaldean origin and was transmitted to India through Greek treatises in the third to the sixth centuries. Scale VII shows the so-called classical Indian system. Full Arabic names of the planets are given here: *mirriḳh* (Mars), *al-shams* (Sun), *al-mushtarī* (Jupiter), *al-zuhra* (Venus), *‘uṭārid* (Mercury), *zuḩal* (Saturn), and *al-qamar* (Moon). Next to them the numbers 10, 20, 30 are shown, for convenience, making up scale VIII.

On scale VI, there is a symbol of a ruling planet for each decan: Mercury ☿, Sun ☼, Venus ♀, Mars ♂, Moon ☾, Saturn ♄, Jupiter ♃. The system here corresponds neither to the Chaldean numerology system (with ruling planets alternating according to the “Star of the Magi”), nor to “Astronomica” by Marcus Manilius (Mars, Sun, Jupiter in Aries, Leo, and Sagittarius...), nor to the alternative Hindu system (Mercury, Sun, Moon in Virgo...). The source of this system is unknown.

Table 10. The table of Decans

| Zodiac sign | 1 st variant (scale VI) | 2 nd variant (scale VII) |
|-------------|------------------------------------|-------------------------------------|
| Aries | Mercury | Mars |
| | Sun | Sun |
| | Venus | Jupiter |
| Taurus | Mars | Venus |
| | Moon | Mercury |
| | Saturn | Saturn |
| Gemini | Moon | Mercury |
| | Saturn | Venus |
| | Jupiter | Saturn |
| Cancer | Mercury | Moon |
| | Venus | Mars |
| | Mars | Jupiter |
| Leo | Moon | Sun |
| | Saturn | Jupiter |
| | Jupiter | Mars |
| Virgo | Mercury | Mercury |
| | Venus | Saturn |
| | Mars | Venera |
| Libra | Moon | Venus |
| | Saturn | Saturn |
| | Jupiter | Mercury |
| Scorpio | Mercury | Mars |
| | Sun | Jupiter |
| | Venus | Moon |
| Sagittarius | Mars | Jupiter |
| | Moon | Mars |
| | Saturn | Sun |

| | | |
|-------------|---------|---------|
| Capricornus | Jupiter | Saturn |
| | Mercury | Venus |
| | Sun | Mercury |
| Aquarius | Venus | Saturn |
| | Mars | Mercury |
| | Moon | Sun |
| Pisces | Saturn | Mercury |
| | Jupiter | Mars |
| | Mercury | Saturn |

2.6 Alidade

The alidade is used to measure the angles of altitudes of celestial and terrestrial objects. In addition to its direct application, the alidade of this instrument performed two other important functions. For example, one half of the alidade is divided into 60 equal divisions (at the right of the photo) to use with the sine scale (see above). The same role is played by the saw-teeth near the central hole.



Fig. 13. The Alidade

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The second half of the alidade (on the left) could be used as a sundial, the sighting plate on the right functioning as the gnomon. Before noon, the divisions 7 to 11 hours are used (in the lower row from right to left): in the afternoon the divisions 2 to 6 (in the upper row from left to right).

3. THE ENIGMAS IN THE ASTROLABE

This astrolabe throws up several enigmas. First, why was the astrolabe belonging to Mīrzā Bāysunghur copied at Lahore in 1587? It appears that sometimes certain very valuable astrolabes are copied to be used as gifts. It is reported that Shāh Abbās of Iran had with him an astrolabe belonging to Ulugh Beg; when the Mughal Emperor Jahāngīr requested him for it, the Shāh generously gifted it to him, but got a copy made for himself (Sarma, 2011, p.112).

Obviously the astrolabe originally belonging to Mīrzā Bāysunghur was in Lahore in the latter half of the sixteenth century. It was considered very exceptional either because of its design or because of the person who originally owned it. Therefore, a patron ordered a copy for himself, on which he desired an inscription stating expressly that it was the copy of the astrolabe belonging to Mīrzā Bāysunghur. This copy is the Moscow Astrolabe.

However, the patron was not fortunate in his choice of artisans for copying the astrolabe. At least two artisans are involved in producing the copy. One apparently had some experience in making astrolabes. He made the rete and the first plate. The rete is made reasonably correctly, but the ecliptic ring is not divided in single degrees. The plate he made carried projections for the latitude of Mecca at $21^{\circ}40'$ on one side and projections for multiple horizons on the other side. The projections for Mecca are done reasonably correctly, but the duration of the longest day engraved on the plate was not correct. He may also have made the alidade.

The rest of the astrolabe, namely the mater and four plates are made by a person who did not understand the functions of the various components of the astrolabe. As we have explained above, he spoiled the symmetrical structure of the geographical gazetteer on the inner side of the mater. On the back of the mater, in the upper left quadrant he drew 67 horizontal parallels instead of 60. On the upper right quadrant, he drew the table of triplicities upside down, and so on. He must have had the original astrolabe of Mīrzā Bāysunghur in front of him, but must have thought that it was not necessary to copy it exactly.

One would have thought that normally the master astrolabe maker would prepare the mater and the rete and that his assistants would make the plates. It is an enigma why this did not happen with the Moscow Astrolabe.

3.1 The Greenwich Astrolabe

Searching for similar astrolabes, we came across an astrolabe made by Yūsuf ibn Hājī al-Jīlānī in 1522 at Gilan near the Caspian Sea. It is now with the National Maritime Museum, Greenwich (Charette, 2005, pp. 220-223). We shall call it the “Greenwich Astrolabe” in the following discussion.

There are several similarities between the two astrolabes at Greenwich and Moscow.

1. The throne (see Fig. 1 and Fig. 14) and the alidade are identically shaped.
2. The latitude plates have a hole on the lower part of the meridian line and the inner surface of the mater has a knob at the same place.
3. One side of the first plate is made for the latitude of Mecca and the other side for multiple horizons.



Fig. 14. Back of the Greenwich Astrolabe (Charette, 2005, p. 221)

4. The horizon plate has 4 extra half-horizons for latitudes $66^{\circ}30'$, 72° , 78° and 84° , together with labels. Besides the four labels related to these four latitudes, the Moscow astrolabe has three more inscriptions engraved outside the circle of equator.
5. In the geographical gazetteer in both astrolabes, the cities are listed from Baghdad onwards and the first 15 cities are identical. More important, Gilan occurs in both the gazetteers.
6. On the back, the shadow square is drawn in the upper right quadrant and inside the shadow square, the table of triplicities is engraved upside down.
7. The astrological table in the lower half is almost the same, the main difference being the symbols used in the Moscow astrolabe for the planets ruling the decans in row VI.

But the rete differs in the two astrolabes. Charette states that the rete in the Greenwich Astrolabe is not original but a replacement (Charette, 2005, p.220). It is likely the original rete of the Greenwich Astrolabe was shaped like the rete in the Moscow Astrolabe.

Is it the Greenwich Astrolabe made by Yusuf ibn Hājī al-Jīlānī in 1522 which was copied at Lahore in 1587? Then the astrolabe maker of Lahore would not have called his production (i.e. the Moscow Astrolabe) a copy of Mīrzā Bāysunghur's astrolabe. Therefore, we have to assume that Mīrzā Bāysunghur's astrolabe looked more or less like the astrolabe of 1522 made by Yusuf ibn Hājī al-Jīlānī, but was different from it. We cannot, at this stage, say how these two astrolabes are related in time or space and why they have so many similarities.

3.2 Other precursors Moscow astrolabe

In the Davids Samling, Copenhagen, there is an astrolabe made by Muḥammad ibn Jaʿfar

ibn ʿUmar al-Aṣṭurlābī called Jalāl in 830 Hijra (AD 1426-27). It is described and illustrated by David A. King as “An Astrolabe for the Sultan Ulugh Beg” (King, 2005, pp. 754-765). On the *kursī* is a long inscription from which the name of the dedicatee has been erased. But King is of the view that that the astrolabe must have been made for Ulugh Beg.

On the inner side of the mater is engraved the tablet of horizons. As in the Moscow astrolabe, here also there are additional half-horizons for latitudes above $66;30^{\circ}$ with explanatory labels. Very likely that the horizon plate in the Greenwich astrolabe made by Yusuf ibn Hājī al-Jīlānī in 1522 was copied from the horizon plate of the Copenhagen astrolabe, but the labels have not been completely copied. Likewise, the horizon plate in the original astrolabe made for Mīrzā Bāysunghur must have been copied from the Copenhagen astrolabe of 1426; the same was copied imperfectly in the Moscow astrolabe.

Some parts of the labels in the Moscow astrolabe are incomprehensible. A comparison with the labels in the Copenhagen astrolabe shows that in the Moscow astrolabe some of the labels are engraved at wrong places. There are other elements, reminiscent of Moscow astrolabe; for example, table of the excess of revolution and the decorative holes on the *kursī* which are enclosed in curls.

If we search for still earlier parallels, we find similar half-horizons for latitudes above $66;30^{\circ}$ in the astrolabe made by Jaʿfar ibn ʿUmar ibn Dawlatshah al-Kirmānī in 774 Hijra (AD 1372) (Gibbs, Saliba, 1984, pp.64-65). In addition, the 20 localities listed in the gazetteer match with those on the Moscow astrolabe; in both astrolabes, there are decorative holes enclosed by curls on the *kursī*.

All predecessors of the Moscow astrolabe have similar sets of astrological tables as well.

3.3 Reconstruction of Mīrzā Bāysunghur's Astrolabe

In the light of the preceding discussion, we can attempt to reconstruct the original astrolabe that was made for Mīrzā Bāysunghur.

1. The throne would be like the throne in the Moscow Astrolabe and in the Greenwich Astrolabe.
2. The limb on the front carries a degree scale as in the Moscow Astrolabe.
3. The rete would be like the rete in the Moscow Astrolabe.
4. The first plate would be like plate I in the Moscow Astrolabe (and also like the first plate in the Greenwich Astrolabe) with horizons on one side and projections for the latitude of Mecca on the other.
5. Other plates would carry correct projections for 8 different latitudes.
6. The geographical gazetteer would be like the same in the Moscow astrolabe but without the distortions.
7. The back would be like the back on the Moscow Astrolabe without the distortions; that is to say, like the back on the Greenwich Astrolabe: sine quadrant in the upper left, single shadow square on the upper right, inside which are accommodated a table of triplicities and a "calendar table"; a large astrological table in the lower half, but with the unusual symbols for planets in row VI.

3.4 Mīrzā Bāysunghur's Astrolabe in Lahore

This astrolabe must have been in Lahore in the second half the sixteenth century and was considered an exceptional astrolabe. Therefore, a patron ordered a copy to be made. Because of the incompetence and carelessness of the astrolabe makers, the copy contains many distortions as detailed above.

This astrolabe also attracted the attention of Allāhdād, the founder of the famous Lahore Family of astrolabe makers, in particular the rete. This rete consists of the Capricorn circle and ecliptic circle which are held together by the meridian bar and east-west bar, both with counter-



Fig. 15. Rete in the astrolabe of 1567 by Allāhdād (photo courtesy Salar Jung Museum)



Fig. 16. Rete in the Moscow astrolabe of 1587 © The State Museum of Oriental Art, Moscow

changes. Small sections of the equator ring are shown in the upper and lower halves. The star pointers generally have the shape of tiger's claws; one or two lobes are added to some of these star pointers.

In his astrolabe of 1567 (Salar Jung Museum, Hyderabad), Allāhdād imitated this rete. However, in his second astrolabe (Museum of the History of Science, Oxford), Allāhdād has an entirely different type of rete, where the star pointers are joined by an ornate floral tracery. This style of floral rete was adopted in almost all the astrolabes made by the descendants of Allāhdād.

However, the type of rete to be found in the Moscow Astrolabe and in Allāhdād's astrolabe of 1567, appears in two more astrolabes of Lahore: an unsigned and undated astrolabe which can be attributed to Allāhdād (National Maritime Museum, Greenwich) and an undated astrolabe by Allāhdād's grandson Muḥammad Muqīm (Lahore Museum). There are slight differences in the retes of these three astrolabes and in the rete of the Moscow astrolabe, but the basic design is the same and the number of star pointers is roughly the same.

Thus, this defective copy of Mīrzā Bāysunghur's Astrolabe solves at least one enigma. Allāhdād and his descendants equipped their astrolabes with beautiful floral retes. Why did they have, in the astrolabe of 1567 and two others, retes so radically different from their standard floral retes? The Moscow astrolabe provides an answer to this question. Because the astrolabe of Mīrzā Bāysunghur enjoyed a great prestige in contemporary circles, they imitated the rete in a few cases.

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