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

Sergei Maslikov* and Sreeramula Rajeswara Sarma**

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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 Mīrzā 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, Mīrzā 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

* Institute for the History of Science and Technology, Moscow; Director of the Large Novosibirsk Planetarium; A. Nevskogo str. 4-39, Novosibirsk, 630075, Russia; E-mail: s.maslikov@gmail.com ; www.astrolabes.ru .

** Formerly Professor of Sanskrit, Aligarh Muslim University; now Höhenstrasse 28, 40227 Düsseldorf, Germany; E-mail: SR@Sarma.de ; www.SRSarma.in.

[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 mm[2] 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 بایسنغر نور هري در سنه ۹۹۶ در بلده لاهور

(naql shud ruqūm ayn asṭurlāb az asṭurlāb haḍrat 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, Gīāṭ 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 wāqi*[c]*,* "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

Table 1. Stars of the Moscow Astrolabe

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

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

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

where r_e is the radius of the equator, ε is the obliquity of the ecliptic (23º30´). 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 *Zīj-i Jadīd-i Sultāni (Zīj-i Gurganī).* This Zīj is often referred to as *Zīj-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.)

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

		Measur. & calcul.			Longitude			Latitude		
	Star	δ	m	α	Astrolabe	Ulugh Beg	Δ	Astrolabe	Ulugh Beg	Δ
1	β Cas	55.9º	0º	0º	30.4º	28º 1'	2.4º	49.4º	50º 48'	-1.4º
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.

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	21º40’	14 hrs 20 min	13 hrs 20 min
Ib	Horizons		
IIa	12º	14 36	12 43
IIb	32º	14 17	14 07
IIIa	30º	13 58	13 57
IIIb	46º	14 40	15 35
IVa	36º	14 30	14 28
IVb	54º	15 20	16 55
Va	42º	14 58	15 05
Vb	50º	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-ᶜarḍ 21 40* (Mecca, the latitude of 21º40’) and *sāᶜāt 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
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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 $\varepsilon = 23^{o}\ 35'$.

1. Half-horizon for 66;30°; below it is engraved افق عرض سو ل ساعاته *(ufq^c arḍ 66;30 sā^{c}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 افق 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 افق عرض عح 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 افق 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 Hājjī 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 التدريج, *(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 kūsā)*, "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}kūsā)*, "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 23º, and not to 12º 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 ک 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 51º29´. The astrolabe shows the value of 86º40´, the difference is 35º11´. *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 هري مرقوم شد نقل از اسطرلاب بايسنغر *(dar 996 hijrī marqūm shud naql az asṭurlāb 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: *ᶜarḍ* = 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.*

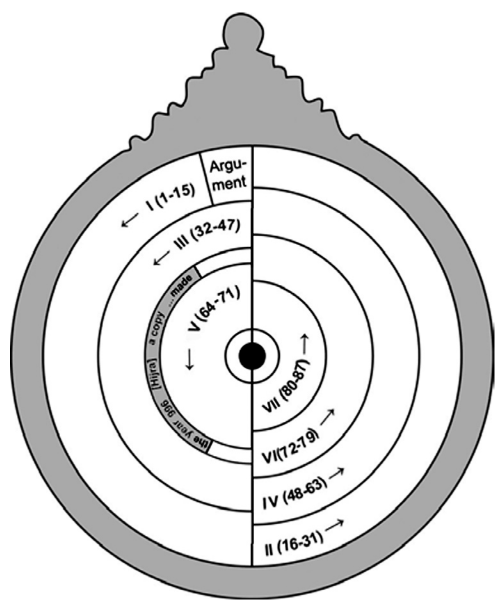

Fig. 6. Diagram showing the dislocation of the circular rows in the gazetteer

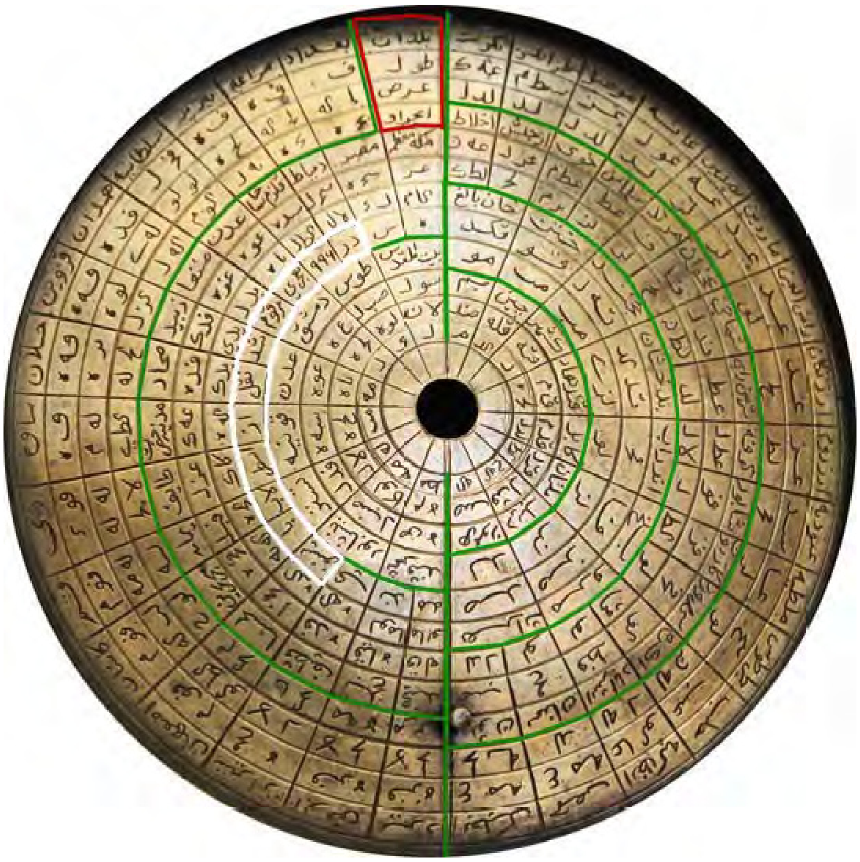

Fig. 7. The geographical gazetteer (coloured lines are added by us)
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Table 6. The geographical gazetteer[6]

	Place Name		Longitude	Latitude	*Inḥirāf*
Row I					
1	Baghdād	بغداد	80º0’	33º25’	13º0’
2	Marāgha	مراغه	82 0	37 20	15 50
3	Tabrīz	تبريز	82 0	38 0	15 30
4	Sulṭāniya	سلطانيه	83 30	36 36	26 40
5	Hamadān	همدان	84 0	35 10	25 30
6	Qazwīn	قزوين	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)	رى	86 20	35 35	31 33
10	Qum	قم	86 40	[35] 45	35
11	Kāshān	كاشان	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	Iṣfahān	اصفهان	86 40	[29] 26	40 23
13	Shīrāz	شيراز	88 0	31 30	51 23
14	Abarqūh	ابرقوه	84 0	31 13	45 0
15	Yazd	يزد	87 0	31 13	47 17
Row II					
16	Ba^{c}albek	بعلبک	70 45	33 15	
17	Hims (Homs)	حمص	70 45	34	
18	Antākya	انطاكيه	71 26	35 30	
19	Ḥalab (Alleppo)	حلب	72	35 50	
20	Tartūs	طرطوس	68	36	
21	Malaṭiya	ملطيه	71	37	
22	Ammūriya	امو ر ئة	64	43	
23	Erzurūm	ارزروم	77	39	
24	Erzincān	ارزنكان	74	38	
25	Rās al-^{c}Ayn	راس العين	74	36	
26	Mārdīn	ماردين	74	37	
27	Nuṣāybin	نصابن	75	37	
28	^{c}Āna	عانه	76 30	34	
29	Mūṣil (Mosul)	موصل	77	34 30	
30	Ṭarābulus (Tripoli)	طرابلس	69 40	34	
31	Tikrīt	تكريت	75 20	34 30	
Row III					
32	Makka Mukarramah (Mecca)	مكه مكرمه	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	^{c}Adan (Aden)	عدن	76 0	11 0	
37	Ṣana^{c}ā	صنعا	76 0	14 30	
38	Zabīd	زبيد	84 20	14 10	
39	Ṣuhār	صحار	84 0	14 20	
40	Madīna (Medina)	مدئنة	75 20	25 0	
41	Ṭāyif	طايف	77 30	21 20	
42	Yamāma	يمامة	82 30	23 0	
43	Jaḥīn	جحئن	83 0	25 15	
44	Laḥsā	لحسا	83 30	24 0	
45	Qaṭīf	قطيف	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	استراباد	89	36	
51	[qut] (Quwait ?)	اكت	82	26	
52	[Sūfard]	سوفرد (?)	88	36	
53	Kāzirūn	كازرون	87	29	
54	Shābūr	شابور	86	30	
55	Kūfa	كوفه	79 30	31 30	
56	Sāmarrā	سامَرّاء (?)	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	خوى	79 40	37 40	
62	[Arjāshan]	ارجاشن	77 30	38	
63	Akhlāṭ	اخلاط	75 50	39 20	
Row V					
64	Bayt al-Maqdis	بيت المقدس	66 30	31 50	30
65	Ṭūs	طوس	92 30	36	45
66	Dimashq	دمشق	70 0	33 0	30
67	ᶜAdan (Aden)	عدن	76	11	45
68	Konya	قونيه	69 0	38 0	42
69	Shustar	شستر	84 30	31 30	35
70	Nīshābūr	نيشابور	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	ديبل	82 30	25 20	
82	Qājirān	قازران	87 30	29	
83	Kābul	كابل	104 40	34 30	
84	Qandahār	قندهار	100 40	33	
85	Kashmir	كشمر	105	30	
86	Chīn (China)	جين	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.

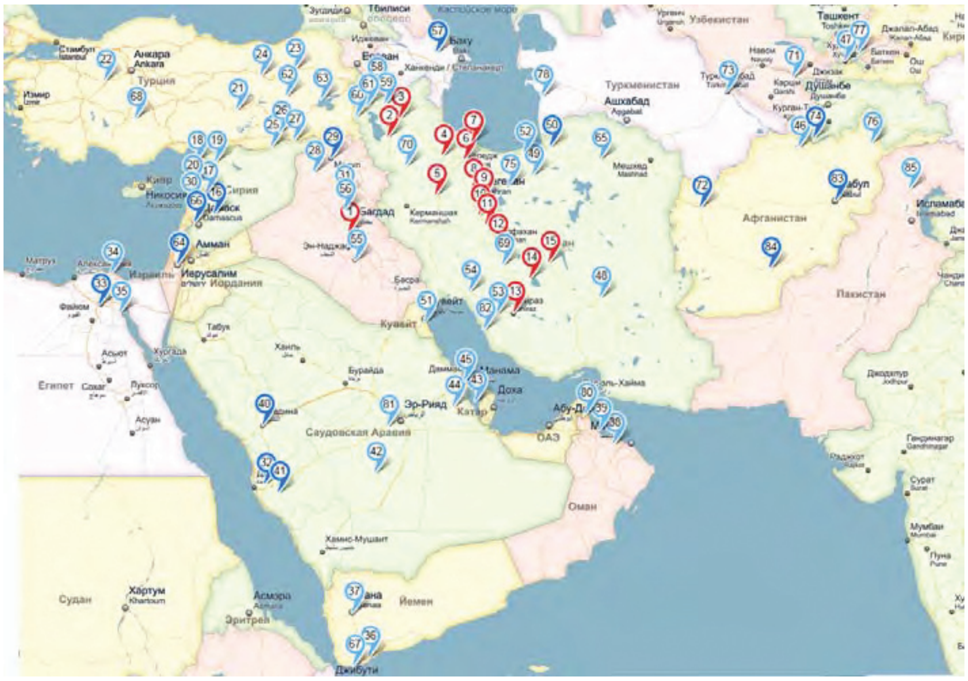

Fig. 8. Distribution of cities featured in the gazetteer. The first 15 cities are highlighted in red. Two easternmost Chinese cities (nos. 79 and 86), which somehow happen to be in the list, are not shown here.

2.5 The Back of the Astrolabe

On the reverse side (back) of the astrolabe there is an inscription on the throne which reads لصاحبه السعادة والسلامة, *(l'sāḥab al-sa^{c}āda wa al-^{c}allāma)*, "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 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".

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.

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	ه Venus	ل Saturn	ه Venus
	ے Jupiter	ر Moon	ک Mercury	خ Mars
	ل Saturn	خ Mars	ے Jupiter	ر Moon
Ruling planets at night	ے Jupiter	ر Moon	ک Mercury	خ Mars
	س Sun	ه Venus	ل Saturn	ه Venus
	ل Saturn	خ Mars	ے Jupiter	ر Moon

The second table engraved on the upper right quadrant is usually designated as *faḍl al-dawr* (excess of revolution); it 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 آحاد اسلين *(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 عشرداث اسلين*(ᶜashar 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 halfof 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-aṣābiᶜ,* 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, ctg 60º = 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
	Saturn	6
Cancer	Mars	7
	Venus	7 [6]
	Mercury	6
	Jupiter	6 [7]
	Saturn	7 [4]
Leo	Jupiter	4 [6]
	Venus	6 [5]
	Saturn	5 [7]
	Mercury	7 [6]
	Mars	6
Virgo	Mercury	7
	Venus	10
	Jupiter	8 [4]
	Mars	7
	Saturn	4 [2]
Libra	Saturn	6
	Mercury	8
	Jupiter	7
	Venus	7
	Mars	2
Scorpio	Mars	7
	Venus	4
	Mercury	8
	Jupiter	5
	Saturn	6
Sagittarius	Jupiter	12
	Venus	5
	Mercury	4
	Saturn	4 [5]
	Mars	4
Capricorn	Mercury	7
	Jupiter	7
	Venus	8
	Saturn	4
Aquarius	Mars	4
	Mercury	7
	Venus	6
	Jupiter	7
	Mars	5
	Saturn	5
Pisces	Venus	12
	Jupiter	4
	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: *mirrīkh* (Mars), *al-shams* (Sun), *al-mushtarī* (Jupiter), *al-zuhra* (Venus), *ᶜuṭārid* (Mercury), *zuḥal (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 ƨ, Jupiter ƨ̲. 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 tableof Decans

Zodiac sign	1st variant (scale VI)	2nd 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°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 Ḥājjī 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°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 in 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 Hājjī 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 Hājjī 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 Jaᶜfar ibn ᶜUmar 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° with explanatory labels. Very likely that the horizon plate in the Greenwich astrolabe made by Yusuf ibn Hājjī 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° in the astrolabe made by Jaᶜfar ibn ᶜUmar 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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