

THE GURMUKHI ASTROLABE OF THE MAHARAJA OF PATIALA

SREERAMULA RAJESWARA SARMA*

(Received 14 August 2011; revised 23 January 2012)

Even though the telescope was widely in use in India, the production of naked eye observational instruments continued throughout the nineteenth century. In Punjab, in particular, several instrument makers produced astrolabes, celestial globes and other instruments of observation, some inscribed in Sanskrit, some in Persian and yet some others in English. A new feature was the production of instruments with legends in Punjabi language and Gurmukhi script. Three such instruments are known so far. One of these is a splendid astrolabe produced for the Maharaja of Patiala in 1850. This paper offers a full technical description of this Gurmukhi astrolabe and discusses the geographical and astrological data engraved on it. Attention is drawn to the similarities and differences between this astrolabe and the other astrolabes produced in India.

Key words: Astrolabe, Astrological tables, Bhālūmal, Geographical gazetteer, Gurmukhi script, *Kursī*, Maharaja of Patiala, Malayendu Sūri, Rahīm Bakhsh, Rete, Rishīkes, Shadow squares, Star pointers, Zodiac signs

INTRODUCTION

For the historian of science and technology in India, the nineteenth century is an interesting period when traditional sciences and technologies continued to exist side by side with modern western science and technology before ultimately giving way to the latter. In the field of astronomical instrumentation, although the telescope was in use throughout the sub-continent and although modern astronomical observatories were set up at Madras in 1786 and at Trivandrum in 1837,¹ production and use of naked eye observational instruments continued throughout the nineteenth century as an adjunct to the pursuit of astronomy according to Sanskrit and Islamic traditions.²

*Höhenstrasse 28, 40227 Düsseldorf, Germany; email: SR@Sarma.de

0.1 ASTRONOMICAL INSTRUMENTATION IN PUNJAB

Especially in Punjab, there seems to have existed a vibrant tradition of producing astronomical instruments pertaining to the Sanskrit and Indo-Persian or Islamic traditions. A notable figure in this connection is Lālā Bhālūmal Lāhūrī (*fl.* 1839-1850),³ a scholarly instrument maker, well versed in Persian and Sanskrit and expert in both the traditions of instrument making, who produced astrolabes, celestial globes, horary quadrants, *Dhruvabhramayantras* and others, some inscribed in Arabic-Persian and others in Sanskrit. He is perhaps the last representative of both the Islamic and Hindu traditions of scientific instrumentation. He was patronized by the Maharaja of Kapurthala, for whom he made a celestial globe in 1842 and received 490 *ashrafī* coins as reward.⁴ His pupil Ghulām Qādir Kapūrthalī is known by an astrolabe produced in 1861.⁵ A contemporary and perhaps an associate of Bhālūmal was Joshi Dhurm Chund (*fl.* 1854-1873) who produced several interesting instruments, some inscribed in Sanskrit, some in Persian and yet some others in English.⁶

0.2 GURMUKHI INSTRUMENTS

A new feature of astronomical instrumentation in Punjab in the nineteenth century is the production of instruments with legends in Punjabi language and Gurmukhi script. Three instruments are known so far, viz. a splendid astrolabe, a rare double quadrant, and a huge Zarqālī universal astrolabe. As will be shown below, the astrolabe was made in 1850 for the Maharaja of Patiala. I have briefly reported about this astrolabe in an earlier publication⁷ and a full-length study is offered in the following pages. The double quadrant and the Zarqālī astrolabe do not contain any information about the maker or about the time of production, but it is quite likely that these were also made about the same time at the court of Patiala. I had the opportunity to personally examine the astrolabe and the quadrant; they appear to have been made by the same instrument maker. The inscription on the double quadrant designates it as a *Cāpa-yantra*. The *Cāpa-yantra* was first described by Brahmagupta in the seventh century and subsequently by many other writers, but this is the only extant specimen known so far.⁸ The Zarqālī astrolabe, with a diameter of about one meter, is one of the largest astrolabes in the world. It is also one of the few Zarqālī astrolabes that are extant. On this astrolabe, most of the inscriptions, including the arguments on the various scales, are engraved in Arabic and Gurmukhi scripts.⁹

The astrolabe and the double quadrant were in a private collection in Germany; after the owner's death a few years ago, they were inherited by his heirs. The Zarqālī astrolabe came up for auction at Christie's of London in 1992¹⁰ and was acquired by a private collector in Milan. It has changed hands recently and moved to a private collection in London.

1.0 THE GURMUKHI ASTROLABE

The inscription¹¹ engraved on the back of the astrolabe states that the astrolabe was produced by the order of Maharaja Narinder Singh of Patiala (r. 1845-1862) on a date corresponding to 14 March 1850 and that the person who got it made (*banāūnevāle*) is Jotishī Śrī Rishīkes and the artisan (*kārīgar*) who made it is Rahīm Bakhsh. It means that the astrologer Rishīkes designed the astrolabe by preparing the technical drawings for it and that the artisan Rahīm Bakhsh fabricated the astrolabe according to the technical drawings and engraved the legends and numerals. In the geographical tables engraved on the astrolabe, the latitudes of all localities are given in degrees and minutes, but the latitude of Kumaon, or rather the city of Almora, is given in degrees, minutes and seconds (see Table 3, no. 38). Such very fine measurement for this one locality would suggest that the astrologer Rishīkes who designed this astrolabe may have hailed from Almora. Probably he was the court astrologer of the Maharaja of Patiala. That he was primarily an astrologer is also evident from the abundance of astrological data on this astrolabe (see sections 1.4.1 and 1.4.2 below).¹²

The inscription is in Punjabi language and Gurmukhi script. All the legends and numerals are in Gurmukhi.¹³ These are deeply engraved and filled with black enamel. The brass astrolabe is in an excellent state of preservation and looks gilded. It has a diameter of 195 mm and a height of 247 mm and is 12 mm thick. The main body or mater of the astrolabe¹⁴ is surmounted by an elaborately carved and reticulated bracket or *kursī* with symmetrical floral pattern in high relief on both sides (Fig. 1). Though the pattern is identical in the front and on the back, the elevations are more pronounced in the front whereas on the back the pattern is softer (compare Figs. 1 and 5). The profiles of the *kursī* on the left and right are formed of tiered lobes. To the tip of the *kursī* is affixed a simple and small shackle, through which passes a large ring with a ribbed outer surface. These two enable the astrolabe to be suspended in a vertical plane and to be rotated



Fig. 1. The Gurmukhi Astrolabe, the front. The alidade is wrongly attached to the front. It should have been fixed on the back

around the vertical axis. The upraised rim of the mater is graduated in 60 divisions and numbered in Gurmukhi numerals serially from 1 to 60, running clockwise. On the inner side of the rim, each division is further subdivided into 6 parts, i.e. into single degrees of arc. The mater accommodates six plates and a rete, all having a diameter of 171 mm.

1.1 The Rete

The rete is delicately crafted (Fig. 2), without overloading it with too many star pointers. The three rings containing the circles of the Tropic of Capricorn, the equator and the ecliptic are held together by the east-west



Fig. 2. The Rete with named Star Pointers

equinoctial bar with two counter changes and the south-north solstitial bar without any counter change. The ecliptic is divided into 12 signs and labelled as follows: *Mekha* (Sanskrit: *Meṣa*), *Brikha* (*Vṛṣa*), *Mithana* (*Mithuna*), *Karaka* (*Karka*), *Siṃgha* (*Siṃha*), *Kaṃnyā* (*Kanyā*), *Tula* (*Tulā*), *Brisacaka* (*Vṛścika*), *Dhana* (*Dhanuḥ*), *Makara* (*Makara*), *Kuṃbha* (*Kumbha*), *Mīna* (*Mīna*). Each sign is further subdivided into groups of 6° and labelled as 6, 12, 18, 24, 30 in counter-clockwise direction. These are further divided into single degrees on the sloped edge of the ecliptic ring, but not labelled.

There are 10 leaf-shaped star pointers outside, i.e., to the south of the ecliptic, and 12 inside, i.e. to the north of the ecliptic. These are listed below in the order of increasing right ascension (Table 1).

Table 1: Stars on the Rete

S. No.	Star Name	Star Name in Sanskrit	Identification	Common Name
1	<i>samudrapachī</i>	<i>samudra-pakṣī</i>	β Cet	Diphda
2	<i>matsodara</i>	<i>matsyodara</i>	β And	Mirach
3	<i>matsodarapāda</i>	<i>matsyodara-pāda</i>	γ And	Almach
4	<i>pra</i>	<i>preta-śira</i>	β Per	Algol
5	<i>rohiṇī</i>	<i>rohiṇī</i>	α Tau	Aldebaran
6	<i>brahāhrada</i>	<i>brahma-hṛdaya</i>	α Aur	Capella
7	<i>āradrā</i>	<i>ārdṛā</i>	α Ori	Betelgeuse
8	<i>lubadhaka</i>	<i>lubdhaka</i>	α CMa	Sirius
9	<i>lubadhakabandhu</i>	<i>lubdhaka-bandhu</i>	α CMi	Procyon
10	<i>mahāpurakha</i>	<i>mahāpuruṣa</i>	α Hyd	Alphard
11	<i>pūrabā phālagunī</i>	<i>pūṛva-phālgunī</i>	δ Leo	Zosma
12	<i>hasata</i>	<i>hasta</i>	δ Cor	Algorab
13	<i>citrā</i>	<i>citrā</i>	α Vir	Spica
14	<i>marīcī</i>	<i>marīci</i>	η UMa	Alkaid
15	<i>svāti</i>	<i>svāti</i>	α Boo	Arcturus
16	<i>sarapadhārasira</i>	<i>sarpadhārī-śira</i>	α Oph	Rasalhague
17	<i>abhijit</i>	<i>abhijit</i>	α Lyr	Vega
18	<i>sravana</i>	<i>śravaṇa</i>	α Aql	Altair
19	<i>rukrapuhara</i>	<i>kukkuṭa-puccha</i>	α Cyg	Deneb
20	<i>matasimukha</i>	<i>aśvamukha</i>	ε Peg	Enif
21	<i>satabhikhā</i>	<i>śatabhiṣā</i>	λ Aqr	
22	<i>purababhādra</i>	<i>pūṛva-bhādrapada</i>	β Peg	Scheat

1.2 The Plates

There are six plates in this astrolabe, each with a small triangular projection at the bottom, which fits into a triangular slot in the rim of the mater (Fig. 3). These six plates serve 11 different cities situated on latitudes ranging from 18° to 52°. One plate face, which we designate as 6b, is devoted to astrological data and will be discussed in section 1.4.2 below. Interestingly, one of the plates is devoted to two capitals. This plate carries on one side projections for the latitude of 30° on which lies Patiala, the capital city of the Maharaja who commissioned this astrolabe. The reverse side of the plate is calibrated for the latitude of 52° on which is situated the City of London (*sahar nandan*), the powerful capital of the British Colonial Power with which the Maharaja of Patiala entered into a treaty of alliance against Maharaja Ranjit Singh of Lahore in 1808. This is reminiscent of the practice in the Lahore astrolabes where one plate is usually devoted to the two imperial cities Agra and Lahore.

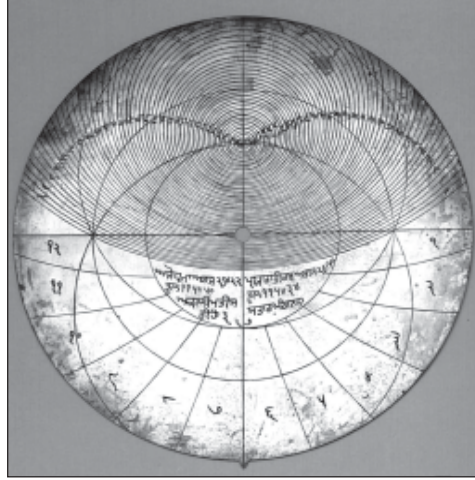


Fig. 3. Plate 3b, calibrated for the latitude of 27°

All the plates (except 6b) carry stereographic projections of the Tropic of Capricorn, the Equator and the Tropic of Cancer as three concentric circles. There is also the projection of the ecliptic circle, which is usually not found on astrolabe plates. The east-west line and north-south line are represented by horizontal and vertical diameters. On this grid is drawn the local horizon for the latitude concerned. Above the local horizon can be seen a series of equal altitude circles or almucantars. These are drawn at intervals of one and half degrees and the alternate lines are labelled as 3, 6, 9 ... 90, both to the east and west of the meridian. This is also unusual, because normally the almucantars have intervals of integer number of degrees. In the lower half of the plates, there are unequal hour lines, which are numbered from the western horizon. On 1a and 1b there are also equal hour lines drawn from the western horizon. All plates carry a complete azimuth circle at 0° . Other azimuth lines vary from plate to plate. On 1a, azimuths are drawn for every 6° above the horizon and numbered along the local horizon only to the left of the meridian; on 1b, 4a, 4b and 6a, there are azimuth lines for every 6° above the horizon, but only partially.

Indo-Persian astrolabes, and also a few Sanskrit astrolabes, contain a special plate, one side of which carries projections for the latitude of 66° . This is roughly equal to 90° minus the obliquity of the ecliptic. This projection is designated as *Ṣafīḥa al-mīzān al-ʿankabūt*, “the plate for measures on the

‘*ankabūt* or *rete*’. The other side of the plate carries the projections of multiple horizons and is entitled *Ṣafīḥa al-afāqiyah*, “the plate of horizons”.¹⁵ The present astrolabe does not contain such a plate.

On all the plates, in the space between the local horizon and the Tropic of Cancer, much data is engraved which is not met with in other Indo-Persian or Sanskrit astrolabes. This data includes the name of the city for which the particular side of the plate is calibrated, its latitude (*araj*, from Arabic *ard*) and longitude (*tūl*, from Arabic *ṭūl*), the climate (*aklīm*, from the Arabic *iqlīm*) and the name of the presiding planet (*satārā*) of this climate.¹⁶ The duration of the longest day at this latitude is not mentioned here, as is generally done on all Indo-Persian astrolabes and also on some Sanskrit astrolabes. As in all medieval astrolabes, the longitudes engraved here are counted from the Fortunate Isles, which are situated to the west of the Straits of Gibraltar in the Atlantic Ocean. Ptolemy used these islands as the reference for measuring the terrestrial longitudes in his *Geography*, and Islamic astronomy adopted the same convention, calling the islands *al-Jazā’ir al-Khalidāt*.¹⁷ These longitudes were in use until 1884 when an international convention adopted the meridian of the Greenwich Observatory as 0° longitude. Since the present astrolabe was produced in 1850, it still uses the longitudes as measured from the Fortunate Isles. However, for the cities of London and Kolkata, it provides just the latitudes and not the longitudes.

More important is that on the plates of this astrolabe are mentioned the names of other cities which lie close to the latitude of the principal city and their latitudes and longitudes. The purpose of this enumeration is that if a city lies close to the latitude for which the plate is calibrated, then the same plate can be used in that city also. This practice does not obtain in the Indo-Persian astrolabes produced in the Lahore family or in Sanskrit astrolabes, but is described in the *Sīrat-i Fīrūz Shāhī*, composed in 1370 at the court of Fīrūz Shāh Tughluq.¹⁸ This practice is met with also in a bilingual astrolabe produced at the court of Jahāngīr in 1616.¹⁹ These three cases attest to the existence in India of a tradition of Indo-Persian astrolabes which is different from that of the Lahore family.

The latitude for which a particular side of a plate is calibrated is mentioned at the junction of the meridian and the tropic of Cancer. The legends on the plates are reproduced below in serial order and translated into English.

Plate 1a for the Latitude of 30°

<i>paṭīālā araj 30/13</i>	<i>kurukhetra araj 30//10//</i>
<i>tūl 111/30</i>	<i>tūl 112/</i>
<i>yah aklīm 3</i>	<i>ihā kā satārā</i>
<i>tīsari hai</i>	<i>maṅgal</i>
30	
Patiala, Latitude 30° 13'	Kurukshetra, Latitude 30° 10'
Longitude 111° 30'	Longitude 112°
This climate	The planet here [is]
is the third 3	Mars

Plate 1b for the Latitude of 52°

<i>sahar naṃdan araj</i>	<i>aklīm cauthī 4</i>
	<i>satārā sūraj</i>
52	
City of London, Latitude	Climate fourth 4
52	Planet the Sun

Plate 2a for the Latitude of 24°

<i>dūsari divārakā araj 24/45</i>	<i>madīnā araj 25//0</i>
<i>tūl 59</i>	<i>tūl 75//</i>
<i>yah aklīm</i>	<i>ihā kā satārā</i>
<i>dūsari hai </i>	<i>brahaspat hai </i>
24	
The second Dwaraka, ²⁰ Lat 24° 45'	Madīnā, Latitude 25° 0'
Longitude 59°	Longitude 75°
This climate	The planet here is
is the second 2.	Jupiter.

Plate 4a for the Latitude of 31°

<i>misar araj 30//30</i>	<i>multān araj 29/40</i>
<i>tūl 63//1</i>	<i>tūl 107//35</i>
<i>aklīm tīsa-</i>	<i>satārā // maṅgal</i>
<i>rī 3</i>	
31	
Egypt, Latitude 30° 30'	Multān, Latitude 29° 40'
Longitude 63° 1'	Longitude 107° 35'
Climate	Planet Mars
third 3.	

Plate 4b for the Latitude of 21°

<i>burhānpur araj 21//21</i>	<i>devagiri araj 20//34</i>
<i>tūl 113//0</i>	<i>tūl 111//0</i>
<i>sūrat ba[m?]bai 20/0 tūl</i>	<i>makkā araj 21//40</i>
50	<i>tūl 76//10</i>
<i>kalakatā araj 22//</i>	<i>duārak araj 22/31</i>
<i>aklīm 3 satrā-</i>	<i>tūl 56</i>
<i>rā bahasapa-</i>	
<i>tā</i>	
21	
Burhanpur, Latitude 21° 21'	Devagiri, Latitude 20° 34'
Longitude 113° 0'	Longitude 111° 0'
Surat, Mumbai, ²² [Lat]20° 20'	Mecca, Latitude 21° 40'
Longitude 50°	Longitude 76° 10'
Calcutta, Latitude 22°	Dwaraka, Latitude 22° 31'
—	Longitude 56°
Climate 3 Planet Jupiter	

Plate 5a for the Latitude of 18°

<i>gaṅgāsāgar araj 18//20</i>	<i>golkuṃḍā haidarābād araj</i>
<i>bījāpur araj 17//17</i>	<i>18//0// tūl 115//19</i>
<i>tūl 118/0</i>	
<i>aklīm dūsarī</i>	<i>yih kā sitārā bi-</i>
2	<i>hasapat hai /</i>
18	
Gangasagar, Latitude 18° 20'	Golconda, Hyderabad, Latitude 18°0'
	Longitude 115° 19'
Bijapur, Latitude 17° 17'	
Longitude 118° 0'	
Climate second	The planet here is Jupiter

Plate 5b for the Latitude of 29°

<i>kuramācala almoḍā araj</i>	<i>naipāl araj 27//10</i>
<i>28//53//20/ tūl</i>	<i>tūl 119//25//</i>
<i>115//19</i>	
<i>yah aklīm</i>	<i>yih kā satārā</i>
<i>tīsarī</i>	<i>maṅgal hai</i>
29	
Kumaon, Almoda, Latitude	Nepal, Latitude 27° 10'
28° 53'20", Longitude 115° 19'	Longitude 119° 25'
This climate is the third	The planet here is Mars.

Plate 6a for the Latitude of 28° 39'

<i>dillī sahar araj 28/39</i>	<i>mathrā araj 26//31//</i>
<i>tūl 114//18//</i>	<i>tūl 113//30//</i>
<i>yah aklīm tīsarī hai</i>	<i>ihā kā satārā maṅgal hai //</i>
28/39	
City of Delhi, Latitude 28° 39'	Mathura, Latitude 26° 31'
Longitude 114° 18'	Longitude 113° 30'
This climate is the third.	The planet here is Mars.

The geographical data engraved on these plates is presented in Table 2 below. Here the columns 2, 3, 4 contain the names, latitudes and longitudes of localities as engraved on the plates. Column 4 contains the modern names of localities. In the case of Indian cities, the names of the localities are followed by the names of states in which these localities are situated. In the case of foreign cities, the names of the respective countries are mentioned. Columns 5 and 6 provide the modern values of latitudes and longitudes.²³

1.2.1 CLIMATES AND THEIR LORDS

The climate is a relic from Ptolemaic geography, where the inhabited portion of the northern hemisphere was divided into seven climates in such a manner that the maximum duration of daylight at the middle of each climate is half an hour longer than in the previous one, and this notion was adopted by the Islamic world. Malayendu Sūri, who wrote a commentary around 1382 on Mahendra Sūri's *Yantrarāja*, which is the first manual on the astrolabe in Sanskrit and which was composed in 1370 at the court of Fīrūz Shāh Tughluq at Delhi,²⁴ erroneously thought that the entire northern hemisphere of the earth, from the equator to the North Pole, is divided into seven parts, for he states as follows in the said commentary on the *Yantrarāja*:²⁵

atha nirakṣāt laṅkāpradeśāt meruparyantaṃ pūrvāpara-dig-vyāpinaḥ sapta vibhāgāḥ tadantarvartinām nagaraṇām akṣāṃśa-jñānārtham ādyaiḥ kalpitāḥ santi. teṣāṃ yavanabhāṣayā ikalemeti saṃjñā kṛtā. śani-guru-bhauma-ravi-śukra-budha-somāḥ kramāt svāminaḥ. evaṃ nirakṣa-laṅkā-pradeśāt pratibhāgam akṣāṃśāḥ trayodaśa navaliptābhir nyūnāḥ 12/51 madhyarekhātaḥ pūrvāpara-bhāgasthā bhavanti. evaṃ yantrāṃśāḥ trayodaśa 13, ṣaḍviṃśatiḥ 26, ekonacatvāriṃśat 39, dvipañcāśat 52, pañcaṣaṣṭiḥ 65, aṣṭasaptatiḥ 78, navatiḥ 90 paryantāḥ. anenaiva krameṇa saptabhāgāḥ syuḥ. param dvipañcāśad akṣāṃśān yāvan manuṣyānāmnivāsah. tadgrataḥ ṣaṭ-ṣaṣṭyamśa-paryantaṃ śīta-bāhulyād andhakārāc ca manuṣyānām alpa eva saṃcārah. tatparataḥ kiṃnara-gandharva-vidyādharasiddhānām pracārā devabhūmayah.

“From the equator (*laṅkā*) at 0° latitude (*nirakṣa*) up to the North Pole (*meru*), seven divisions that stretch to the east and west have been conceived by the ancients for knowing the latitudes (*akṣāṃśa*) of the cities which lie in these divisions. They were given the designation of *iklīm* in Arabic language. The lords of these [divisions] are Saturn, Jupiter, Mars, the Sun, Venus, Mercury and the Moon respectively. Thus, [starting]

Table 2: Geographical Data engraved on the Plates

S. No.	Name of the Locality	Lat	Long	Modern Name	Lat N	Long E
1	Paṭīālā	30° 13'	111° 30'	Patiala, Punjab	30° 20'	76° 24'
2	Kurukhetra	30° 10'	112° 00'	Kurukshetra, Haryana	30° 00'	76° 27'
3	Naṃḍan	52°	—	London, UK	51° 30'	00° 07'
4	Dūsarī Duvārakā	24° 45'	59°	?		
5	Madīnā	25° 0'	75°	Medina, Saudi Arabia	24° 28'	39° 36'
6	Lāhaur	31° 50'	109° 20'	Lahore, Pakistan	31° 32'	74° 20'
7	Kaṃḍhār	33° 0'	107° 40'	Kandahar, Afghanistan	31° 37'	65° 43'
8	Kāsmīr	35° 1'	108°	Srinagar, J&K	34° 05'	74° 48'
9	Kābal	34° 30'	104° 40'	Kabul, Afghanistan	34° 31'	69° 10'
10	Ajodhyā	27° 22'	115° 50'	Ayodhya, UP	26° 48'	82° 12'
11	Prayāg Tīrath	26° 50'	115° 34'	Allahabad, UP	26° 59'	79° 00'
12	Mīsr	30° 30'	63° 1'	Cairo, Egypt	30° 03'	31° 15'
13	Multān	29° 40'	107° 35'	Multān, Pakistan	30° 11'	71° 28'
14	Burhānpur	21° 21'	113° 0'	Burhanpur, MP	21° 18'	76° 13'
15	Sūrat	20° 0'	50°	Sūrat, Gujarat	20° 58'	72° 54'
16	Baṃbai	20° 0'	50°	Mumbai, Maharashtra	18° 58'	72° 49'
17	Kalakatā	22°	—	Kolkata, WB	22° 34'	88° 22'
18	Devagiri	20° 34'	111° 0'	Daulatabad, Maharashtra	19° 56'	75° 14'
19	Makkā	21° 40'	76° 10'	Mecca, Saudi Arabia	21° 25'	39° 49'
20	Duārak	22° 31'	56°	Dwarka, Gujarat	22° 14'	69° 01'
21	Gaṃgāsāgar	18° 20'	—	Gangasagar, WB	21° 48'	88° 06'
22	Bījāpur	17° 17'	118° 0'	Bijapur, Karnataka	16° 50'	75° 42'
23	Golkumḍā/ Haidarābād	18° 0'	115° 19'	Hyderabad, AP	17° 22'	78° 28'
24	Kurmācal/ Almoḍā	28° 53'20''	115° 19'	Almora, Kumaon Uttarakhand	29° 37'	79° 40'
25	Naipāl	27° 10'	119° 25'	Kathmandu, Nepal	27° 43'	85° 19'
26	Dillī	28° 39'	114° 18'	Delhi	28° 40'	77° 13'
27	Mathrā	26° 31'	113° 30'	Mathura, UP	27° 28'	77° 41'

from the equator at 0° latitude, each division covers a stretch of 13° of latitude less 9 minutes, i.e. 12° 51', to the east and west of the prime meridian (*madhya-rekhā*). Thus [these seven divisions reach roughly] up to 13, 26, 39, 52, 65, 78 and 90 degrees of the instrument. The seven divisions follow the same sequence. However, human habitation obtains [only] up to 52°. Beyond this, up to 66°, there is little habitation of humans because of excessive cold and darkness. Thereafter, there are the lands of gods (*devabhūmayah*) where Kīṃnaras, Gandharvas, Vidyādhara and Siddhas²⁶ dwell.”

But, unlike Malayendu Sūri, Abū al-Faḍl explains correctly the system of the climates in the third volume of his *Āl 'in-i Akbarī* and also mentions the latitudes at the beginning and middle of each climate and the duration of the longest days at these climates.²⁷ Such data in tabular form is engraved on the back of some Indo-Persian astrolabes.²⁸ The latitude values for the boundaries vary according to the value given to the obliquity of the ecliptic.²⁹ However, on the astrolabe plates, the climate is not mentioned along with the latitude of a locality, as is done on the present astrolabe. It is also obvious that the person who designed this astrolabe follows Malayendu Sūri's erroneous interpretation of the system, for it is only according to Malayendu Sūri that London on the latitude of 52° could belong to the fourth climate. In the correct system, however, London would lie beyond the boundary of the seventh and final climate which varies between $49^\circ 52'$ and $50^\circ 33'$.³⁰ The lords of the climates mentioned on the plates are also according to Malayendu Sūri. The instrument maker made an error in the climate number of plate 4b. The plate is calibrated for the latitude of 21° and the climate is given there as 3, but it should be 2. The lord is mentioned correctly as Jupiter.

1.3 The Geographical Gazetteer

All Indo-Persian astrolabes and some Sanskrit astrolabes carry on the inner surface of the mater an elaborate geographical table or gazetteer containing the names, latitudes and longitudes of several localities in India and Central Asia. While the geographical data engraved on the plates is essential for the use of the astrolabe, the geographical gazetteer has no immediate connection with the use of the astrolabe. It is engraved just as a kind of *aide-mémoire*. Even so, such lists are historically important. Though the values themselves are not of great significance, these lists of geographical coordinates of places give us an idea of the transmission of the geographical knowledge and also how certain wrong or inaccurate ideas are perpetuated because authors sometimes borrow data uncritically from the earlier sources. An interesting aspect of these lists is that sometimes the name of a region stands for the capital city; e.g. Kashmir for Srinagar, Tibet for Lhasa, Nepal for Kathmandu, or Tailang/Tilang for Golconda (modern Hyderabad). Sometimes wrong values are perpetuated, e.g. Uḍīṣā, in the sense of Puri Jagannath, the principal city of Orissa, is generally given a high value of 27° while the correct latitude is $19^\circ 48'$.³¹



Fig. 4. Geographical Gazetteer on the inner side of the Mater

In the present astrolabe, a geographical gazetteer is engraved on the inner side of the mater, continuously in five annular rings, containing the names and latitudes (but not longitudes) of 62 localities (Fig. 4). It is reproduced in Table 3 below.

The last two entries refer to the boundaries of China and Russia. About China it is stated *cīn āraṃbh pūrab 21° 0'*; *cīn had uttar 55° 0'*, “the beginning of China in the east 21°; the boundary of China in the north 55°.” This is roughly correct, because the southernmost tip of the land mass of China extends in the east up to the latitude of 21° and its northern boundary reaches up to about 53°. About Russia it is stated: *rūs āraṃbhā 40° 0'* *rūs had uttar 66°*, “the beginning of Russia is 40° 00'; the boundary of Russia in the north 66°.” In Central Asia, the Russian empire reached up to the latitude of 40°, but in the north it extends much beyond 66°.

The notion of latitude 66° as the boundary of the inhabited world is expressed in Ring V, in what appears to be a mixture of Punjabi and Sanskrit:

Table 3: Geographical Gazetteer engraved on the Mater

S. No.	Name of the Locality	Latitude	Modern Name	Modern Latitude N	Modern Longitude E
Ring I					
1	Lamkā ³²	1° 30'	Sri Lanka	06° -10°	80° -82°
2	Pūrabam yamkotī ³³	5° 0'	?		
3	Somnāth	16°	Somnath, Gujarat	20° 53'	70° 24'
4	Bījāpar	17° 17'	Bijapur, Karnataka	16° 50'	75° 42'
5	Tailang	18° 0'	Hyderabad, AP	17° 22'	78° 28'
6	Gaṃgāsāgar	18° 20'	Gangasagar, WB	21° 38'	88° 05'
7	Golakumḍā	18° 0'	Hyderabad, AP	17° 22'	78° 28'
8	Sūrat	20° 0'	Surat, Gujarat	20° 56'	72° 54'
9	Baṃbaī	20° 0'	Mumbai, Maharashtra	18° 58'	72° 49'
9	Devgirī	20° 34'	Daulatabad, Maharashtra	19° 56'	75° 14'
10	Burhānpur	21° 21'	Burhanpur, MP	21° 18'	76° 13'
11	Makā	21° 40'	Mecca, Saudi Arabia	21° 25'	39° 49'
12	Ḍhākā Baṃgālā	22° 0'	Dhaka, Bangladesh	23° 43'	90° 24'
13	Kālakatā	22° 0'	Kolkata, WB	22° 34'	88° 22'
14	Bhurākachā	22° 0'	Bharuch, Gujarat	21° 42'	72° 58'
15	Raivatakācal ³⁴	22° 31'	Girnar, Gujarat	21° 29'	70° 30'
16	Ahamadābād	23° 0'	Ahmedabad, Gujarat	23° 01'	72° 37'
17	Baḍā(?)yac	23° 0'	?		
18	Ujjain	23° 30'	Ujjain, MP	23° 10'	75° 46'
19	Khaibar	24° 0'	Khybar Pass, Pakistan	34° 06'	71° 05'
20	Madīnā	25° 0'	Medina, Saudi Arabia	24° 28'	39° 36'
21	Ajmer	26° 0'	Ajmer, Rajasthan	26° 26'	74° 37'
22	Kāsi	26° 15'	Varanasi, UP	25° 19'	83° 00'
Ring II					
23	Dhārā	26° 20'	Dhar, MP	22° 36'	75° 17'
24	Kanaṃj	26° 20'	Kannauj, UP	27° 03'	79° 55'
25	Bikāner	26° 24'	Bikaner, Rajasthan	28° 01'	73° 17'
26	Gvāliyar	26° 30'	Gwalior, MP	26° 13'	78° 10'
27	Mathrā	26° 31'	Mathura, UP	27° 30'	77° 41'
28	Jodhpur	26° 36'	Jodhpur, Rajasthan	26° 17'	73° 02'
29	Āgarā	26° 43'	Agra, UP	27° 10'	78° 01'
30	Jaipur	26° 47'	Jaipur, Rajasthan	26° 55'	75° 49'
31	Gājīpur ³⁵	27° 01'	?		
32	Lakhanaū	26° 30'	Lucknow, UP	26° 51'	80° 55'
33	Uḍīsā	27°	Puri, Orissa	19° 48°	85° 51'
34	Ajudhyā	27° 22'	Ayodhya, UP	26° 48'	82° 12'

S. No.	Name of the Locality	Latitude	Modern Name	Modern Latitude N	Modern Longitude E
35	Koīl	28° 0'	Aligarh, UP	28° 02'	78° 17'
36	Naipāl	28° 50'	Kathmandu, Nepal	27° 43'	85° 19'
37	Dilī	28° 40'	Delhi	28° 36'	77° 13'
38	Kumāū	28°53'20''	Almora, Kumaon Uttarakhand	29° 37'	79° 40'
39	Hisār	29° 40'	Hissar, Haryana	29° 10'	75° 43'
40	Multānā	29° 40'	Multan, Pakistan	30° 11'	71° 28'
Ring III					
41	Kurukhetra	30° 10'	Kurukshetra, Haryana	30° 00'	76° 27'
42	Paṭiyālā	30° 13'	Patiala, Punjab	30° 20'	76° 24'
43	Mīsar	30° 30'	Cairo, Egypt	30° 03'	31° 15'
44	Lāhūr	31° 50'	Lahore, Pakistan	31° 32'	74° 20'
45	Khamdhār	33°	Kandahar, Afghanistan	31° 37'	65° 43'
46	Kābil	34° 30'	Kabul, Afghanistan	34° 31'	69° 10'
47	Kāsmīr	35° 1'	Srinagar, J&K	34° 05'	74° 48'
48	Balap	36° 41'	Balkh, Afghanistan	36° 45'	66° 54'
49	Bhoṭalāvācīnā ³⁶	37° 0'	?		
50	Tavrej	38° 0'	Tabriz, Iran	38° 04'	46° 18'
51	Samrkaṃd	39° 34'	Samarqand, Uzbekistan	39° 39'	66° 57'
52	Tibat	40° 0'	Lhasa, Tibet	29° 39'	91° 07'
53	Kubīnā	41° 01'	?		
54	Khutan	42° 0'	Khotan, China	37° 04'	80° 02'
Ring IV					
55	Kāsgar	44° 0'	Kashgar, China	39° 20'	74° 04'
56	Kurkurūm ³⁷	46° 0'			
57	Bulgār ³⁸	49° 0'			
58	Imglīstān Naṃdan	52° 0'	London, England	51° 30'	0° 05'
59	Cīn āraṃbh pūrab	21° 0'			
60	Cīn had uttar	55° 0'			
61	Rūs āraṃbhā	40° 0'			
62	Rūs had uttar	66°			

daraje 66 uprāt pācbhaut kā cārābhāvaḥ | had 90 devabhūmi (?) This roughly translates to “Beyond the degrees 66 [of latitude] there is an absence of the movement of live beings. [Up to the] boundary of 90 [degrees, it is] the land of gods.” Here the instrument is merely reflecting the Ptolemaic notion of the oecumene or the inhabited world, as understood in medieval Sanskrit texts.

Nearly all the localities, save four (viz. Dūsarī Duārakā, Prayāg Tīrath, Duārak and Mathrā), which are mentioned on the plates are repeated in the gazetteer. In one case, there is a substantial difference: the latitude of Nepal is engraved as $27^{\circ} 10'$ on the plate whereas it has a much higher value of $28^{\circ} 50'$ in the gazetteer. The latitude of Delhi is given as $28^{\circ} 39'$ on plate 6a (this is the traditional value from at least 1370); it is rounded off to $28^{\circ} 40'$ in the gazetteer.

1.4 The Back of the Astrolabe

The back of the astrolabe is divided into four quadrants by the vertical and horizontal diameters (Fig. 5). Here the upper half of the rim carries a degree scale. The inner band of the scale is divided into single degrees and the upper band into groups of 6° and labelled as 6, 12, ... 90; 90 ...12, 6. This is the scale on which the altitudes of the heavenly bodies are measured by means of the alidade. The rim around the lower left quadrant is blank, but the one around the lower right quadrant carries a tangent scale. The outer band is divided into unequal units carrying the numbers 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, starting from the vertical diameter and proceeding towards the horizontal diameter. Each of these divisions is further sub-divided into 5 units in the inner band.

The upper left quadrant bears a sine-cosine grid, consisting of 30 vertical parallels and 30 horizontal parallels. Shadow squares or tangent and co-tangent tables are engraved in the two lower quadrants. The square on the left is for a gnomon of 12. Here both the horizontal and vertical scales are divided into 12 divisions each and numbered accordingly. These divisions are further subdivided into 2 units in the outer band. Below the horizontal scale is engraved the label *narabhā saralā*, “gnomon shadow, straight,” (i.e. umbra recta) and to the left of the vertical scale is the label *narabhā pratilomā*, “gnomon shadow, reverse” (i.e. umbra versa).

The square on the right is meant for a gnomon of 7 feet. Here both the horizontal and vertical scales are divided into 7 divisions each and numbered accordingly. These divisions are further subdivided into 2 units in the outer band. Below the horizontal scale is engraved the label *padachāyā*, “shadow of feet, straight,” and to the right of the vertical scale is the label *pādachāyā pratilomā*, “shadow of feet, reverse”.

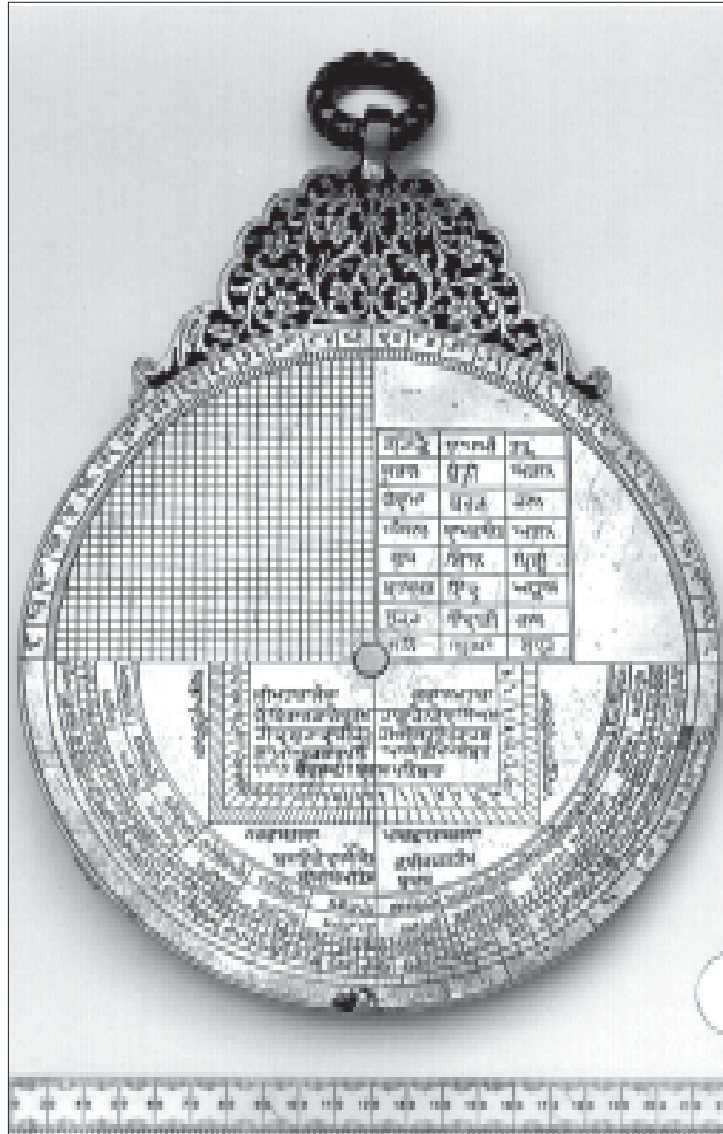


Fig. 5. The Back of the Astrolabe

Islamic astrolabes make a distinction between two kinds of shadows, viz., *zill-i aşābi'a*, “shadow in digits,” and *zill-i aqdām*, “shadow in feet”. The first are the shadows thrown by a gnomon which is divided into 12 “digits” and the second are those cast by a gnomon divided into 7 “feet”.

Sanskrit astrolabes generally ignore this distinction and call both units of measurement as “*aṅgula*”. Thus they call the two kinds of shadows as *dvādaśāṅgula-śaṅku-chāyā*, “shadow cast by a gnomon of 12 *aṅgulas*,” and *saptāṅgula-śaṅku-chāyā*, “shadow cast by a gnomon of 7 *aṅgulas*”. The present astrolabe maintains the distinction and calls the shadow cast by a gnomon of 12 digits as *narabhā* and that of a gnomon of 7 feet as *pādachāyā*.

Besides these trigonometric tables, the back of the astrolabe carries much astrological data. Indo-Persian astrolabes contain such astrological tables on the back,³⁹ but Sanskrit astrolabes usually do not. Plate 6b also carries astrological data. The astrological data in both these places appear to have been derived from sources like Kalyāṇavarman’s *Sārāvalī* (ca. 800).⁴⁰ Like the geographical gazetteer, these astrological tables also do not have any direct bearing on the functions of the astrolabe. These are incorporated into the astrolabes, like the geographical gazetteer, as *aide-mémoires*.

1.4.1 Astrological Data on the Back of the Astrolabe

The upper right quadrant contains a table showing the lords or the presiding deities (*suāmī*, Sanskrit *svāmī*) and the essence or the related element (*tatba*, Sanskrit *tattva*) of the 7 planets (*grah*), which is reproduced below.

<i>Grahā ke</i> (of the planet)	<i>Suāmī</i> (lord)	<i>Tatba</i> (essence)
<i>Sūraj</i> (the Sun)	<i>Baṃhī</i> (Vahni)	<i>Agan</i> (fire)
<i>Caṃdramā</i> (the Moon)	<i>Baruṅ</i> (Varuṅa)	<i>Jal</i> (water)
<i>Maṃgal</i> (Mars)	<i>Svāmakārita</i> (?) ⁴¹	<i>Agan</i> (fire)
<i>Budh</i> (Mercury)	<i>Bisn</i> (Viṣṇu)	<i>Prithbī</i> (earth)
<i>Brahaspat</i> (Jupiter)	<i>Iṃdra</i> (Indra)	<i>Ākās</i> (ether)
<i>Sukar</i> (Venus)	<i>Iṃdrāṅī</i> (Indrāṅī)	<i>Jal</i> (water)
<i>Sani</i> (Saturn)	<i>Brahamā</i> (Brahmā)	<i>Vāyu</i> (wind)

In the lower half, the shadow squares are enclosed by four concentric semi-circles. Reading from outside and from the right to the left, these semi-circles contain respectively

1. the names of the 27 lunar mansions (*nakṣatras*);

2. *nakṣatra-pādas*, i.e. one-fourth parts of the *nakṣatras*, but labelled for each three successive *nakṣatras*, as 1, 2, 3, ... 10, 11, 12. Each 9 of these *nakṣatra-pādas* constitute the related zodiac sign, as shown in the next semi-circle;
3. zodiac signs with a suffix ^o*rās* (Sanskrit *rāśi*); and
4. the lords of the signs, with the prefix *svāmī*.

This semi-circular table is an improvement on similar tables in Indo-Persian astrolabes, in so far as it has only 27 lunar mansions and not 28, as it shows the correspondence between the lunar mansions and zodiac signs more graphically through the *nakṣatra-pādas* and as it also adds the lords of the signs. It is interesting that in each scale, the items are to be read from the right to the left, as in Islamic astrolabes.

The names of the 27 lunar mansions engraved here are as follows, with the cognate Sanskrit terms in parentheses: 1. *Asanī* (*Aśvinī*), 2. *Bharaṇī* (*Bharaṇī*), 3. *Kritakā* (*Kṛttikā*), 4. *Rohaṇī* (*Rohiṇī*), 5. *Mragas* (*Mṛgaśirā*), 6. *Ādrā* (*Ādrā*), 7. *Punarvas* (*Punarvasu*), 8. *Puṣya* (*Puṣya*), 9. *Aslekh* (*Āśleṣā*), 10. *Maghā* (*Maghā*), 11. *Pūrbā Phā* (*Pūrva-phālgunī*), 12. *Utrā Phā* (*Uttara-phālgunī*), 13. *Hasata* (*Hastā*), 14. *Citrā* (*Citrā*), 15. *Svāti* (*Svāti*), 16. *Visākhā* (*Viśākhā*), 17. *Anurādhā* (*Anurādhā*), 18. *Jeṣṭhā* (*Jyeṣṭhā*), 19. *Mūla* (*Mūla*), 20. *Pūrbākhā* (*Pūrvāṣādhā*), 21. *Utrākhā* (*Uttarāṣādhā*), 22. *Sravana* (*Śravaṇa*), 23. *Dhaniṣṭhā* (*Dhaniṣṭhā*), 24. *Satabhikha* (*Śatabhiṣā*), 25. *Pūrvābhā* (*Pūrva-bhādrapada*), 26. *Utrābhā* (*Uttara-bhādrapada*), 27. *Revatī* (*Revatī*).

The zodiac signs and their lords mentioned in scales 3 and 4 are as follows:

Mekh Rās: *Svāmī Maṅgal* (Aries: Mars), *Brikh Rās*: *Svāmī Sukar* (Taurus: Venus), *Mithan Rās*: *Svāmī Budh* (Gemini: Mercury), *Karak Rās*: *Svāmī Caṁdramā* (Cancer: Moon), *Siṁgh Rās*: *Svāmī Sūraj* (Leo: Sun), *Kaṁnyā Rās*: *Svāmī Budh* (Virgo: Mercury), *Tul Rās*: *Svāmī Sukar* (Libra: Venus), *Brisacak Rās*: *Svāmī Maṅgal* (Scorpio: Mars), *Dhan Rās*: *Svāmī Brahaspat* (Sagittarius: Jupiter), *Makar Rās*: *Svāmī Saniscar* (Capricorn: Saturn), *Kuṁbh Rās*: *Svāmī Saniscar* (Acquarius: Saturn), *Mīn Rās*: *Svāmī Brahaspat* (Pisces: Jupiter).⁴²

1.4.2 Astrological Data on Plate 6b

Some more astrological data is engraved on the reverse side of Plate 6 (Fig. 6). Here the lower half contains a sine-cosine grid of 30 horizontal and 60 vertical lines. In the upper half there are ten concentric semi-circular columns containing astrological information in tabular form.

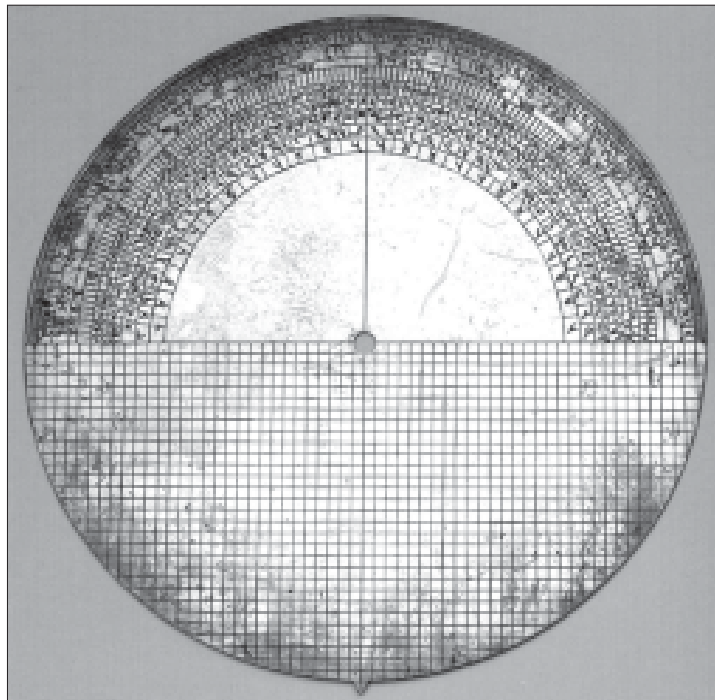


Fig. 6. Plate 6b with astrological tables in the upper half and the sine-cosine grid in the lower half

In Indian astrology, the zodiac signs are sub-divided in ten different ways (*daśa-varga*) and to each part of such a sub-division a planet is assigned as its lord. These combinations are used in making predictions in horoscopy.⁴³ In the ten semi-circular columns in the upper half, the zodiac signs are divided in different ways. The material in the columns is arranged sometimes from the left to the right and sometimes in the opposite direction. Reading from the outside, these columns contain the following data.

1. Divisions of single degrees.

2. Groups of six degrees labelled as 6, 12, 18, 24, 30 from the right to the left. These are divisions of the zodiac signs in the column below.
3. Twelve zodiac signs, shown by the serial number and the name, written from the right to the left.
4. The same twelve divisions containing a three-fold classification of signs, according to which Aries, Cancer, Libra and Capricorn are said to be *cara* (unsteady), *āsakhira* (?) (steady) and *dasakāva* (?) (mixed).⁴⁴
5. Each sign is subdivided into 12 parts (*dvādaśāṃśā*) of $2\frac{1}{2}^\circ$ each. The subdivision on the right bears the same serial number as the zodiac sign, which means that the lord of the sign is also the lord of the first 1/12th division.
6. Each sign is subdivided into 9 parts (*navāṃśā*) of $3\frac{1}{3}^\circ$ each. These are numbered from right to left in groups of 12 as 1, 2, 3, ... 10, 11, 12.
7. Each sign is subdivided into 7 parts (*saptāṃśā*) of $4\frac{2}{7}^\circ$ each. These parts are numbered from right to left in groups of 12 as 1, 2, 3, ... 10, 11, 12.
8. Each sign is subdivided into 5 parts (*pañcāṃśā*) of 6° each. These parts are labelled with the letters of a mercantile script known as the Lāṇ script.
9. Each sign is subdivided into 3 parts or decans (*dreṣkāṇa*) of 10° each. The cells are filled with different serial numbers of the signs. For example, the three decans under Aries bear the numerals 1, 5, 9; it means that the lords of the three decans are the same as the lords of the sign nos. 1, 5, 9, viz. Mars, Sun and Jupiter.⁴⁵
10. Each sign is subdivided into 2 parts (*horā*) of 15° each. The cells are filled alternatively with the numerals 4 and 5. These numbers also stand for the lords of the signs bearing these numbers. Thus sign 4 is Cancer and its lord is the Moon; sign 5 is Leo and its lord is the Sun.⁴⁶

1.5 The Alidade

The alidade (length 196 mm) in this astrolabe is surprisingly simple without any decoration or graduations (see Fig. 1). On this alidade, the two sights are affixed, which are rather too close to the centre. There is a pin to hold all the parts together. It is the convention that the wedge that holds the

pin firmly in position is shaped like a horse; but here it is shaped like a bird with upraised wings.

1.6 The Inscription on the Back

On the back, inside the shadow squares is an inscription (Fig. 7) which reads thus:



Fig. 7. The inscription on the back of the astrolabe

*sri mahārāje rājagāna mahārā-
jedhirāja rājesvara mahārāje nareṃdrasiṃgha ma-
hīṃdra bahādra jī ke huha<ka>m so yahu jaṃtrarāj ba-
ṇāyā || sarkār paṭiyāle kī mo<hur> || saṃbat
1907 caitra sudī 1 brahasapatibār |*

“This astrolabe (*jaṃtrarāj*) was made by the order of Sri Mahārāje Rājagāna Mahārājedhirāja-Rājesvara-Mahārāje Nareṃdrasiṃgha Mahīṃdra Bahādrajī. [Under] the Seal of the Government of Patiala. Saṃbat 1907 Caitra sudī 1 Thursday (= Thursday 14 March 1850).”

Below the shadow squares are engraved the names of the designer and of the maker in the left and right halves respectively:

*banāūṇevāle jota- kārīgar rahīm
sī sī rikhīkes bakhsh*

“He who caused to be made (i.e. he who designed) Jotishī Śrī Rishīkes. The maker (*kārīgar*, lit. artisan) Rahīm Bakhsh.”

2.0 CONCLUSION

Generally Sanskrit astrolabes were designed by Brahmin astronomers who prepared the technical drawings and then they were fabricated by artisans according to these drawings. There is often a mismatch between the two, resulting in uneven graduations and faulty orthography in the inscriptions. In the present case the collaboration between the astrologer Rishīkes and the instrument maker Rahīm Bakhsh was quite successful. Both appear to be familiar with Indo-Persian astrolabes. The latter is a skilful instrument maker. His excellent workmanship can be compared with that of the best astrolabes produced in the Lahore family, in particular the very ornate *kursī*.

One may ask why these people in Punjab produced naked eye instruments in the nineteenth century when telescopes were easily available. It is obvious that they did not consider these instruments purely as tools to be discarded the moment an improved variety becomes available, but treated them as important elements of traditional culture which one cultivated. The local Maharajas of Kaputhala, Patiala and other principalities, patronized these endeavours.

Though the production of astrolabes continued up to the early years of the twentieth century, the present astrolabe is arguably the last important astrolabe produced in India. It is significant that in the production of this astrolabe all three major communities of Punjab took part: the Sikh prince who commissioned the astrolabe, the Hindu astrologer who designed it and the Muslim instrument maker who produced it.

ACKNOWLEDGEMENTS

I am deeply indebted to the late owner of this astrolabe who graciously allowed me to study this astrolabe and other instruments in his collection and provided me with black and white photographs of high quality, some of which are reproduced with this article. I wish also to thank Dr Jaspal Singh, Cambridge MA, for his help in the decipherment of the Gurmukhi script and in the translation of the Punjabi sentences on this astrolabe.

NOTES AND REFERENCES

1. Cf. Kocchar & Narlikar 1995, pp. 9-14.
2. Cf. Sarma 2001.

3. On Bhālūmal, see Savage-Smith 1985, pp. 52-55, 235-236, 244-245, 304; Sarma 2010a, s.v. Bhālūmal.
4. Cf. Savage-Smith 1985, pp. 235-236.
5. This astrolabe is in the National Museum, New Delhi; it is illustrated in Gupta 1985, p. 179, item 272. There are some other unsigned astrolabes in this museum which can be attributed to Ghulām Qādir on stylistic grounds.
6. Sarma 2003, pp. 78-84; Sarma 2008b, pp. pp. 29-31.
7. See Sarma 2008b, pp. 35-38.
8. For a brief description and an illustration of this double quadrant, see *ibid*, pp. 33-35.
9. Cf. Sarma 2010b.
10. Christie's 1992, item no. 119, pp. 48-49.
11. For the full text of the inscription and its translation, see section 1.6 below.
12. Rishīkes is the vernacular form of Sanskrit Hṛṣīkeśa. On an Arabic astrolabe that had been reworked with additional inscriptions in Sanskrit, the name of Jyotirvid Hṛṣīkeśa of Kūrmācala (Kumaon) was engraved as the owner of the astrolabe; cf. Sarma 2010a, 75-108, esp. 105-106. Perhaps this Hṛṣīkeśa is the same as the Rishīkes who designed the present Gurmukhi astrolabe.
13. I learnt the Gurmukhi script with the help of a very useful internet resource "Omniglot: writing systems & languages of the world," accessible at <http://www.omniglot.com/> and deciphered much of the Gurmukhi engravings on the astrolabe. Subsequently, Dr Jaspal Singh, Cambridge, MA, kindly solved the difficulties in the script and helped me in translating the Punjabi inscriptions.
14. On the history of the astrolabe in India, see Sarma 1994; Sarma 1999; Sarma 2000. On the components of the astrolabe and their functions, see Hartner 1985; North 1974; Khareghat 1950.
15. Cf. Khareghat 1950, pp. 32-39.
16. On climates and their lords, see section 1.2.1 below.
17. Cf. Abū al-Faḍl, *Āī'in-i Akbarī*, vol. 3, pp. 39-40.
18. Cf. Sarma 2000.
19. Cf. Sarma 2011.
20. The Dūsarī Dvārakā or the Second Dvārakā must be an important city, presumably on the West Coast of India, to be allotted a side of a plate. But I fail to locate a city of this name. The longitude value of 59 is clearly too low.
21. This is obviously an error in engraving. Instead of drawing a vertical line to separate the degrees from the minutes, the engraver drew the numeral by mistake.

22. Surat and Mumbai are given the same latitude of $20^{\circ} 20'$ and an absurdly low longitude of 50° , which would place the two cities in Central Africa! Their actual latitudes are more than 2° apart, even though the longitudes are almost the same. See tables 2 and 3 below for the actual values.
23. According to the "Directory of Cities and Towns in World Global Gazetteer," version 2.2., accessible at <http://www.fallingrain.com/world/index.html> . The seconds in the values of the latitudes and longitudes are omitted here.
24. Cf. Sarma 1999; Sarma 2000.
25. Mahendra Sūri, *Yantrarāja*, p. 18.
26. These are different classes of semi-divine beings of Indian mythology.
27. Abū al-Faḍl, *Āī'in-i Akbarī*, vol. 3, pp. 51-54.
28. Cf. Sarma 2011, p. 98.
29. For a table of climates with corresponding latitudes for different values of obliquity, see King 2005, p. 927.
30. Ibid, p. 927.
31. Cf. Sarma 2011, pp. 93-94.
32. In Indian astronomy, Laṅkā represents the zero latitude and zero longitude. Therefore, it is not clear why the value of $1^{\circ} 30'$ is given to its latitude. As for the island Sri Lanka, its latitude extends from 6° to 10° .
33. It is difficult to interpret this locality. In Indian astronomy, Yamakoṭi is a notional point on the equator, 90° east of Laṅkā. Then its latitude should be 0° .
34. Raivatakācal, a mountain named Raivataka or Raivata, is mentioned frequently in the epics. Varāhamihira, *Bṛhatsaṃhitā*, 16.19, states that the Raivataka mountain lies in the south-western division. In his interpretation of this passage, Shastri 1996, vol. 1, p. 55, opines that it is the hill opposite Mount Girnar and that it is sometimes identified with Girnar itself.
35. There are several localities named Gazipur in the Indian subcontinent, but none seem to have this value for latitude.
36. The name seems to refer to Tibet (*bhoṭa*) and China (*cīna*) but its exact significance is not known.
37. Karakoram or Karakorum is the name of a mountain range spanning the borders between Pakistan, India and China. The given latitude of 46° is far too high to pertain to any point on this mountain range.
38. The gazetteers on the Indo-Persian and Sanskrit astrolabes end with Bulgār or Bulghar region and city. According to Gibbs & Saliba, p. 201, "the name was given to the land of the Slavs north of the Caspian Sea around the Volga River."
39. Astrological data on the back of Indo-Persian astrolabes is discussed by Kaye 1918, Appendix B: Astrological Tables, pp. 119-126.

40. Cf. Pingree 1971, pp. 26-29; Pingree 1981, p. 88. Several chapters of the *Sārāvalī* have been translated into German by Türistig 1980, pp. 154-294.
41. Kalyāṇavarman, *Sārāvalī* 4.12 states that the lords of the planets are Agni, Varuṇa, Skanda, Viṣṇu, Indra, Śacī and Brahma; cf. Türistig 1980, p. 163. Accordingly the lord of Mars should be Skanda, also known as Kārtikeya and Ṣaṇmātrka. Is Svāmakārita a corruption of Ṣaṇmātrka?
42. *Sārāvalī* 3.11; cf. Türistig 1980, p. 157.
43. *Sārāvalī* 1.3; cf. Türistig 1980, pp. 53-66.
44. *Sārāvalī*, 3.20; cf. Türistig 1980, p. 159.
45. *Sārāvalī* 3.14 states that the lords of the three decans of any zodiac sign are respectively the lords of the same sign and of the fifth and ninth signs; cf. Türistig 1980, p. 158.
46. *Sārāvalī* 3.14 states that the lords of the *horās* in a sign with an odd number are the Sun and the Moon respectively and that the lords of the *horās* in a sign with an even number are the Moon and the Sun respectively; cf. Türistig 1980, p. 158.

BIBLIOGRAPHY

- Abū al-Faḍl, *Āī'in-i Akbarī*, vol. 3, tr. H. S. Jarrett, revised by Jadu-Nath Sarkar, Calcutta 1948; reprint: Frankfurt 1993, pp. 39-40.
- Christie's 1992. Christie's, South Kensington, London, Auction Catalogue of 24.09.1992.
- Gibbs & Saliba 1984. Sharon Gibbs with George Saliba, *Planispheric Astrolabes from the National Museum of American History*, Washington, DC.
- Gupta 1985. S. P. Gupta (ed), *Masterpieces from the National Museum Collection*, New Delhi.
- Hartner 1985. Willy Hartner, "The Principles and Use of the Astrolabe" in: idem, *Oriens-Occidens: Ausgewählte Schriften zur Wissenschafts- und Kulturgeschichte, Festschrift zum 60. Geburtstag*, Hildesheim 1985, pp. 287-311.
- Kocchar & Narlikar 1995. Rajesh Kocchar & Jayant Narlikar, *Astronomy in India: A Perspective*, Indian National Science Academy, New Delhi.
- Kaye 1918. G. R. Kaye, *The Astronomical Observatories of Jai Singh*, Calcutta 1918; reprint: New Delhi 1982.
- Khareghat 1950. M. P. Khareghat, *Astrolabes*, M. P. Khareghat Memorial Volume II, edited by Dinshaw D. Kapadia, Bombay.
- King 2005. David A. King, *In Synchrony with the Heavens: Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization*, vol. 2: Instruments of Mass Calculation, London-Boston.
- Mahendra Sūri, *Yantrarāja of Mahendra Sūri with the Commentary of Malayendu Sūri*, ed. Kṛṣṇaśaṃkara Keśavarāma Raikva, Bombay 1936.

- North 1974. J. D. North, "The Astrolabe," *Scientific American*, 230 (January 1974) 96-106.
- Pingree 1971. David Pingree, *Census of the Exact Sciences in Sanskrit*, Series A, vol. 2, Philadelphia.
- Pingree 1981. David Pingree, *Jyotiḥśāstra: Astral and Mathematical Literature*, Wiesbaden.
- Sarma 1994. Sreeramula Rajeswara Sarma, "The Lahore Family of Astrolabists and their Ouvrage," *Studies in History of Medicine and Science*, 13 (1994), 205-224; reprinted in: Sarma 2008a, pp. 199-222.
- Sarma 1999. Sreeramula Rajeswara Sarma, "Yantrarāja: The Astrolabe in Sanskrit," *IJHS* 34 (1999)145-158; reprinted in: Sarma 2008a, pp. 240-256.
- Sarma 2000. Sreeramula Rajeswara Sarma, "Sulṭān, Sūri and the Astrolabe," *IJHS* 35 (2000)129-147; reprinted in: Sarma 2008a, pp. 179-198.
- Sarma 2001. Sreeramula Rajeswara Sarma, "Some Indo-Persian Astronomical Instruments of the early Nineteenth Century," *Khuda Bakhsh Library Journal*, No. 123 (April 2001) 1-16.
- Sarma 2003. Sreeramula Rajeswara Sarma, *Astronomical Instruments in the Rampur Raza Library*, Rampur.
- Sarma 2008a. Sreeramula Rajeswara Sarma, *The Archaic and the Exotic: Studies in the History of Indian Astronomical Instruments*, New Delhi.
- Sarma 2008b. Sreeramula Rajeswara Sarma, "Indian Astronomical Instruments in German Collections," XXX. Deutscher Orientalistentag, Freiburg, 24.-28. September 2007. Ausgewählte Vorträge, hrsg. im Auftrag der DMG von Rainer Brunner et al. Online-Publikation, Februar 2008. <http://orient.ruf.uni-freiburg.de/dotpub/sarma.pdf>, pp. 29-31.
- Sarma 2010a. Sreeramula Rajeswara Sarma, "The Makers, Designers and Patrons of Sanskrit Astronomical Instruments: An Alphabetical Directory of Names and Related Inscriptions," *Journal of the Oriental Institute*, Baroda, 60.1-2 (2010).
- Sarma 2010b. Sreeramula Rajeswara Sarma, "Indian Astronomical Instruments in Italy," paper presented at the XXIX Symposium of the Scientific Instrument Commission at Florence, Italy, on 4-9 October 2010.
- Sarma 2011. Sreeramula Rajeswara Sarma, "A Bilingual Astrolabe from the Court of Jahāngīr," *Indian Historical Review*, 38.1 (June 2011) 77-117.
- Savage-Smith 1985. Emilie Savage-Smith, *Islamicate Celestial Globes: Their History, Construction and Use*, Washington, DC.
- Shastri 1996. Ajay Mitra Shastri, *Varāhamihira's India*, New Delhi.
- Türsting 1980. Hans-Georg Türsting, *Das System der indischen Astrologie*, Wiesbaden.