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The Astrolabe by Bulhomal and Pīr Bakhsh of 1841 CE: A Unique Testimonial to an Intercultural Collaboration

Sreeramula Rajeswara Sarma and Mubashir Ul-Haq Abbasi
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1 INTRODUCTION

THE ASTROLABE

The term "astrolabe" denotes primarily the planispheric northern astrolabe; it is planispheric because it is a two-dimensional representation of the heavens in relation to the earth; it is northern because it contains pointers only to those stars which are situated to the north of the Tropic of Capricorn. Other variations such as the spherical astrolabes, linear astrolabes, north-south astrolabes are theoretical curiosities and have no practical relevance.[1]

The astrolabe consists of a heavy circular plate with an upraised rim, called "mater." In the recess inside the rim are stacked a series of plates made for different latitudes; at the top of these plates rests a perforated disc called "rete", which contains stereographic projections of the ecliptic and of the positions of some prominent stars. The front part of the rim is divided in degrees of arc, so also the rim of the back of the mater. All these plates are perforated at the centre. A pin is inserted in this central hole and made fast with a wedge in the front. At the centre of the back is pivoted the alidade, which carries sighting plates at each end. For observation, the astrolabe needs to be suspended in a vertical plane. Therefore, a triangular suspension bracket is affixed to the top of the mater. To the upper tip of this suspension bracket is attached a shackle and to it a ring. With this ensemble several functions can be performed.

Before using the astrolabe, the astronomer places the appropriate latitude plate beneath the rete; for example, if the user is in Lahore, he places that side

1 The literature on the astrolabe is vast. The best introductions can be found in Hartner 1968; Gibbs and Saliba 1984; Morrison 2007.

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of plate which is calibrated for the latitude of Lahore, roughly 32°. Then, moving the alidade along the rim of the back, he measures the altitude of the sun if it is daytime, or the altitude of a prominent fixed star if it is night. When the rete is adjusted to the sun's or to the star's altitude, then the rete and the plate below it together simulate the starry heavens upon the observer's locality for that particular moment. Then one can read off the time in equal hours or in unequal hours; one can also find the rising and setting times of the sun and stars, their times of meridian transit, and so on. One can also identify the four pivots, namely the ascendant, the lower mid-heavens, the descendant, and the culmination, with which the horoscope is cast. The astrolabe can also be used as an analogue computer for solving trigonometric problems. It can also be employed in land surveys for measuring the heights or depths of objects and for estimating distances.

The astrolabe was invented in Greece, but its origins are obscure. Stereographic projection, which is an essential feature of the astrolabe, was said to have been developed by Hipparchus of Nicaea around 150 BCE. John Philoponus of Alexandia wrote a treatise on the astrolabe in the sixth century CE; it is the earliest extant work on this instrument.[2] But no actual astrolabe produced in Greece is extant. Then in the seventh century Bishop Severus Sabokt composed a treatise on the astrolabe in the Syriac language, which is also extant.[3]

It is through such Syriac writings that the astrolabe was introduced to the Islamic world where it attained its fullest development. Muslims adopted it enthusiastically, especially because it helped them determine the times of prayers including the time for morning and night prayers (*ᶜIshā'* عشاء and *Fajr* فجر) when the sun is below the horizon, and also the direction of the *qibla,* towards which they faced for offering their prayers.

Several learned scholars like al-Khwarizmī and al-Farghānī composed treatises in Arabic in the ninth century. The production of astrolabes also went hand in hand. The earliest dated astrolabe was made by Muḥammad ibn ᶜAbdullāh Nasṭūlus in 315 AH (926–27 CE). It is preserved in the Islamic Archaeological Museum at Kuwait.[4] It is somewhat plain, but sophisticated design and ornamentation can be seen in an astrolabe fashioned by Ḥāmid ibn Khiḍr al-Khujanḍī in 374 AH (984–85 CE).[5] In the Islamic world, the astrolabe maker was not merely a metal worker; he was a scholar with a thorough knowledge of spherical trigonometry; he designed the astrolabe and also fabricated it himself. Therefore he bore the soubriquet *Asṭurlābī* (اصطرلابى).

In the subsequent centuries, astrolabe production spread to different regions including the Muslim Spain. It is from this Muslim Spain that the science of the

2 Gunther 1932: 61–81.
3 Gunther 1932: 82–103.
4 King 1995: 76–83.
5 King 2004: 503–517.

astrolabe was transmitted to the Christian Europe through the Latin translations of Arabic texts. In Europe also many manuals were composed, and a large number of astrolabes produced until the advent of the telescope in the seventeenth century.

Moreover, the Arabic astrolabe left its impact on the technical vocabulary of our times. A large number of terms that reached Europe through the astrolabe still survive in many European languages; thus for example "zenith" (from سمت‌الراس *samt al-rās*), "nadir" (from نظير *nazīr*) and "azimuth" (from السمت *al-sumt*) are derived from the Arabic. In an article, imaginatively titled "Arabic in the Sky," Lebling states that some 210 stars in the sky carry names that are derived from the Arabic,[6] such as "Aldeberan" (from عين‌الثور *ᶜAyn al- Thawr,* α Tauri), "Algol" (from راس‌الغول *Ra's al Ghūl*, β Persei), "Altair" (from النسر الطائر *al-Nasr al-Ṭā'ir*, α Aquilla), "Betelgeuse" (from يدالجوزااليمنى *yad al-Jawzā' al-Yumnā,* α Orionis), "Caph" (from كف‌الخضيب *Kaff al-Khaḍīb*, β Cassiopeiae), "Deneb" (from ذنب‌الدجاجه *Dhanab al-Dajājaḥ*, α Cygni) and so on.

THE ASTROLABE IN INDIA

Astrolabe may have been introduced into India by the great polymath Abū al-Rayhān Muḥammad ibn Aḥmad al-Bīrūnī during his stay in the north-western India in the early eleventh century. He claims to have composed a book on the astrolabe in Sanskrit verse.[7] No such book has survived, but it is entirely possible that al-Bīrūnī may have shown the astrolabe and explained its functions to his Hindu or Jain interlocutors. In the second half of the fourteenth century, Sulṭān Fīrūz Shāh Tughluq (r. 1351–1388) promoted the production of astrolabes at his court in Delhi and sponsored manuals on the construction and use of the astrolabe both in Persian and in Sanskrit.[8] But the astrolabes produced at his court have not survived. Of the manuals on the astrolabe, some extracts from the Persian manual can be found in the Persian chronicle *Sīrat-i Fīrūz Shāhī* (سيرت فيروز شاہی) of 1370.

But the Sanskrit manual did survive. It was composed by a Jain monk Mahendra Sūri in 1370. He was so impressed by the versatile functions of the astrolabe that he called it *Yantrarāja* (يانترا راجه), "the king of [astronomical] instruments" in Sanskrit. That is also the title of his manual. Since that time, astrolabe came to be called *Yantrarāja* in Sanskrit. Mahendra Sūri's pupil Malayendu Sūri wrote a commentary on his teacher's work around 1378.[9] Mahendra Sūri's *Yantrarāja* was very popular, for there exist about a hundred manuscript copies of

6 Lebling 2010: 25; see also Kunitzsch and Smart 1986.
7 Sachau 1910: vol 1, 137.
8 Sarma 2000: 142.
9 Sarma 2021, see the Appendix D1: "The Yantrarāja of Mahendra Sūri with Malayendu Sūri's commentary, some extracts with English translation."

this work. Moreover, in the subsequent centuries, at least sixteen other Sanskrit manuals were composed on the astrolabe by different scholars.[10] Together with the Sanskrit manuals, astrolabes also must have been produced with Sanskrit labels and Devanagari numerals.

Since then the study and production of astrolabe followed two distinct traditions. Muslims studied the Arabic and Persian manuals and produced astrolabes with Arabic and Persian labels and numerals. Because they were produced in the Persianate culture of India, they are called Indo-Persian astrolabes. Hindus and Jains studied Sanskrit manuals and produced Sanskrit astrolabes. The earliest dated Indo-Persian astrolabe was produced in 1567–68 and earliest surviving Sanskrit astrolabe is dated 1605.

THE FAMILY OF ASTROLABE-MAKERS OF LAHORE

Sometime in the sixteenth century an astrolabe maker named Allāhdād set up workshop at Lahore with the patronage of the second Mughal emperor Humāyūn. In memory of this royal patronage, Allāhdād's descendants describe themselves as the descendants of Ustād Allāhdād Asṭurlābī Lāhūrī Humayūnī. In this Lahore workshop Allāhdād and his descendants produced astrolabes and celestial globes. The astrolabes were richly decorated with a large number of star pointers. Some of the astrolabes were too large for actual observation; these were meant as presentation pieces for high nobility at the Mughal court. In particular, the astrolabes fashioned by Muḥammad Muqīm (fl. 1621–1659) and his nephew Ḍiyāʾ al-Dīn Muḥammad (fl. 1637–1680) display meticulous precision in geometrical projections, fine workmanship in metal and a high degree of artistic excellence. Besides the common planispheric northern astrolabes, Ḍiyāʾ al-Dīn also created at least one North-South astrolabe and a huge Zarqālī universal astrolabe.

In the case of celestial globes, they followed a special technique. Outside India, celestial globes were first made as two separate hemispheres and then joined together. The Lahore instrument makers, on the other hand, cast the globes as single pieces by the lost wax process. Here also Ḍiyā' al-Dīn Muḥammad excelled in the rendition of beautiful constellation figures which he engraved on his globes.

In spite of their close association with Mughal nobility, none of these Lahore instrument makers are mentioned in any contemporary Mughal chronicles. The history of this family had to be reconstructed from the extant specimens of their work. This was done by the first author (i.e., Sreeramula Rajeswara Sarma) in *A Descriptive Catalogue of Indian Astronomical Instruments*. This catalogue lists 105

10 Sarma 1999.

astrolabes[11] and thirty-six celestial globes,[12] that were produced by the various members of the Lahore family between the years 1567 and 1691 and that are now preserved in various museums and private collections. Many others may have been lost. Thereafter the production ceased in the Lahore workshop, probably because of the decline of the Mughal authority, lack of patronage and disturbed political conditions. In the eighteenth century, no Indo-Persian astrolabe or celestial globe was produced either at Lahore or anywhere else in the subcontinent, nor was any Sanskrit astrolabe.

LĀLAH BULHOMAL LĀHORĪ

Then towards the middle of the nineteenth century, when the European telescope was making the traditional naked-eye instruments redundant, the two traditions of Indo-Persian instruments and Sanskrit instruments came together in the work of a remarkable person by name Lālāh Bulhomal Lāhorī who was associated with the court of the Sikh rulers of the Kapurthala State. It was mentioned above that no member of the Lahore family of instrument-makers is mentioned in any contemporary chronicle; the same is the case with Bulhomal in the nineteenth century. The first author of this paper put together the diverse instruments made by Bulhomal[13] and concluded that,

> Bulhomal was the true and the last representative of both the traditions of Indo-Persian and Sanskrit astronomical instruments. ...Bulhomal produced well-crafted astrolabes and celestial globes with inscriptions and legends either in Arabic-Persian or in Sanskrit. He also fashioned Dhruvabhrama-yantras and Turīya-yantras of Sanskrit tradition. His oeuvre consists of about twenty-eight instruments of excellent workmanship belonging to eleven different varieties. ...In 1839 itself he produced at least four instruments of three different types. At this rate of production, he may have produced between 1839 and 1851 many more instruments than the twenty-eight which are known to us. No instrument-maker in India is known to have produced as many varieties of instruments as Bulhomal did, that too with labels in three different languages.[14]

Bulhomal also crafted the unusual North-South astrolabes. The details of these twenty-eight instruments are shown in Table 1.

11 Sarma 2021: section A.
12 Sarma 2021: section F.
13 See Sarma 2015; see also Sarma 2021: 1713–1716 *et passim*.
14 Sarma 2015: 260.

Table 1: Astronomical instruments signed by or attributable to Lālah Bulhomal Lāhorī.

S. No.	*Category*	*Year of manufacture*	*Signed or attributable*	*Present location*
		Astrolabes		
1	Indo-Persian	1841	signed	Lahore
2	Indo-Persian	1849	signed	London
3	Indo-Persian	n.d.	attributable	Dublin
4	Indo-Persian	n.d.	attributable	not known
5	Sanskrit	n.d.	attributable	Rampur, India
6	Sanskrit	n.d.	attributable	Srinagar
7	Sanskrit	n.d.	attributable	Oxford
8	Indo-Persian North-South	1851	signed	not known
9	Indo-Persian North-South	n.d.	signed	not known
10	Sanskrit	n.d.	attributable	Srinagar
11	Sanskrit	n.d.	attributable	Srinagar
		Celestial globes		
12	Indo-Persian	1842	signed	London
13	Indo-Persian	1842	signed	Karachi
14	Indo-Persian	n.d.	attributable	Illinois, USA
15	Indo-Persian	n.d.	attributable	London
16	Indo-Persian	n.d.	attributable	Delhi
17	Indo-Persian	n.d.	attributable	Srinagar
18	Indo-Persian	n.d.	attributable	not known
19	Sanskrit	1839	signed	London
20	Sanskrit	n.d.	attributable	New York
21	English	n.d.	attributable	London
		Dhruvabhrama-yantra		
22		1839–40	signed	New York
23		n.d.	attributable	London
		Horary Quadrant		
24		n.d.	signed	Oxford
		Jyotiḥsattā		
25		1839	signed	London
26		1839	signed	New Delhi
27		n.d.	attributable	New York
		Un-named instrument		
28		n.d.	attributable	New York

Figure 1: Front view of the Astrolabe (photo by Mubashir Ul-Haq Abbasi).

2 THE ASTROLABE BY BULHOMAL AND PĪR BAKHSH

Among the twenty-eight instruments listed above, there is one astrolabe which was designed by Bulhomal but was fabricated by Pīr Bakhsh. It is preserved today in the Lahore Museum.[15] In 1984, Dr Saif ur Rahman Dar, the then Director of the Lahore Museum, published a description of this astrolabe.[16] Later, when the first author (i.e., Sreeramula Rajeswara Sarma) was compiling *A Descriptive Catalogue of Indian Astronomical Instruments*, the second author (Mubashir Ul-Haq Abbasi) provided photographs and details of this astrolabe and of other instruments from the museums in Pakistan. Sarma included a brief description of this astrolabe in his catalogue.[17] Now we two jointly offer a comprehensive description of this unique astrolabe in the following pages.

It is unique in many respects. First, Bulhomal's other Indo-Persian and Sanskrit astrolabes are small devices measuring about 150 mm in diameter, whereas this one is a massive piece measuring 235 mm in diameter, 305 mm in height, 20 mm in thickness and weighing 7 kg. Second, at 20 mm, the present astrolabe is unusually thick. The large space provided by this thickness was used for engraving a very long inscription in two lines, with letters shown in relief against a hatched background. While the inscription here was engraved by Pīr Bakhsh, Bulhomal himself attempted the same technique eight years later. In his Indo-Persian astrolabe that he dedicated to Sir Henry Elliot, the dedication was likewise engraved on the thick edge, with letters in relief against a hatched background.[18] In fact, these are the only two cases where engraving was done on the thick edge of an astrolabe. The contents of this long inscription are also unique as will be shown below (pp. 242, ff.). Furthermore, the members of the Lahore Family, especially Muḥammad Muqīm and his nephew Ḍiyā' al-Dīn Muḥammad filled the retes of their astrolabes with a large number of star-pointers to show off their expertise. Bulhomal, quite pragmatically, included just twelve star-pointers in some astrolabes and only seven in some others, because these are adequate for actual observation. In contrast, the rete of the present astrolabe has as many as twenty-six star-pointers. Bulhomal used Arabic-Persian numerals in his other Indo-Persian astrolabes; but in the present astrolabe *Abjad* notation is employed in most places. Moreover, the back of the present astrolabe displays an entirely new feature, namely a graph showing angles and their cotangents engraved inside the shadow squares (see tables 10–13 on pages 241–242 below).

The astrolabe is richly decorated. The thick edge of the *kursī* is ornamented with floral motifs (see Figure 2). In the rete, the two slender rings representing

15 # MM 1649.

16 Dar 1994: 165–198.

17 Sarma 2021: item B024.

18 Sarma 2021: fig. B021.4.

Figure 2: Decorated edge of the Throne (photo by Mubashir Ul-Haq Abbasi).

the Tropic of Capricorn and the Celestial Equator are filled with a pleasing decorative pattern (see Figure 6). The main inscriptions on both sides of the *kursī* and on the thick circular edge are engraved in elegant Nasta'līq calligraphy.

COMPONENTS OF THE ASTROLABE

THE MATER

The main body of this astrolabe consists of a heavy circular plate with an upraised rim on one side. This heavy plate is called "Mater" (Latin for "mother", translated from Arabic اُم *ᶜumm*); it is called "mater" because it holds the other parts inside the rim. The suspensory bracket, the rim and the mater appear to have been cast as one piece. The limb (وجه *wajah*), which is the front side of the rim, is divided in single degrees, and groups of 6° are numbered in the *Abjad* notation from 6° to 360°, starting at the south point at the top and proceeding clockwise.

THE SUSPENSORY APPARATUS

The suspensory apparatus generally consists of a triangular bracket (كرسى *kursī*, "throne"), a swivel (عروه *ᶜurwah*) and a large ring (حلقه *ḥalqa*). It is very unusual that in the present case a 275 mm long roller-chain is attached to the swivel instead of a ring. It is not known whether this chain is original or was added later on. The triangular bracket is called *kursī* (throne) because on some of the early Islamic astrolabes the "throne verse" (*āyat al-kursī*, Qur'ān, Surah 2:255) was engraved which reads: "His throne extends over the heavens and the earth"). But on this throne another verse from the Qur'ān is engraved.

The throne is solid without any perforations. It is very wide at the base; the profiles are made up of ogees (i.e., S-shaped forms) at the base and at the top with two lobes in the middle. The thick edge is richly decorated with floral motifs.

The front and the back carry inscriptions where the letters are shown in relief. The front is engraved with the first few words from a verse from the Qur'ān

Figure 3: Front of the Throne (photo by Mubashir Ul-Haq Abbasi).

Figure 4: Back of the Throne (photo by Mubashir Ul-Haq Abbasi).

(verse no. 59 of Sura الانعام *al In^c^ām*) with two names of Allah added on either side:

يا حافظ يا حفيظ

و عنده مفاتح الغيب لا يعلمها الا هو

يا ناصر و يا نصير

yā Ḥāfiẓ yā Ḥafīẓ

wa ^c^indahu miftāḥ al ghaib lā ya^c^alamuha illā hu

yā Nāṣir yā Naṣīr

O Protector, O Preserver,
With Him are the keys of the unseen [that] no one knows but [He] …
O Helper, O Supporter.

On the back of the throne are engraved three lines of inscriptions; the letters are shown in relief and the empty spaces are filled with floral ornamentation. The uppermost line bears the name of the astrolabe maker thus:

عمل پیر بخش لاہوری

ᶜamal Pīr Bakhsh Lāhorī

Work of Pīr Bakhsh Lāhorī.

The two lines immediately below contain a Persian couplet which describes the astrolabe as a device to show the events on the Earth and in the Heavens:

کسے کہ مصحف ترا نظارہ کند
ذکر خیر فال بیند استخارہ کند

kasay keh muṣḥaf-i turā nazzārah kunad
zikr-i khair fāl binad istakhārah kunad

Anyone who sees your [astrolabe's] face,
Sees and finds a good omen when he tries to seek help [from Allah] for the future.

The two lines engraved on either side in the third row contain another couplet:

بیا این اصطرلاب با چشم یقین بنگر
بروج و انجم افلاک و بر روئے زمین بنگر

biyā eīn uṣṭarlāb ba chashm-i yaqīn binigar
burūj wa anjum-i aflāk wa bar rūay zamīn binigar

Come and hold this astrolabe with trust and confidence,
Know the constellations, stars in the sky and [the events] on the earth.

It is not known who the author of these couplets is: Bulhomal who designed the astrolabe, or Mawlwī Ghulām Muḥammad who commissioned it, or somebody else?

THE RETE

The rete (Arabic العنکبوت *al- ᶜankabūt*) is well-crafted and artistically decorated (Figs. 5, 6). The narrow segment of the circle on the periphery represents the Tropic of Capricorn. The thin arc just above it represents the celestial equator. The outer rim of the very broad ring above that stands for the ecliptic. The centre of the rete represents the North Celestial Pole. The Capricorn ring, the ecliptic ring and the small, perforated ring at the centre are held together by a horizonal bar. The ecliptic ring is divided into the twelve zodiac signs and labelled with their names, starting from the vernal equinox (which is at the junction of ecliptic

Figure 5: Rete of the Astrolabe (photo by Mubashir Ul-Haq Abbasi).

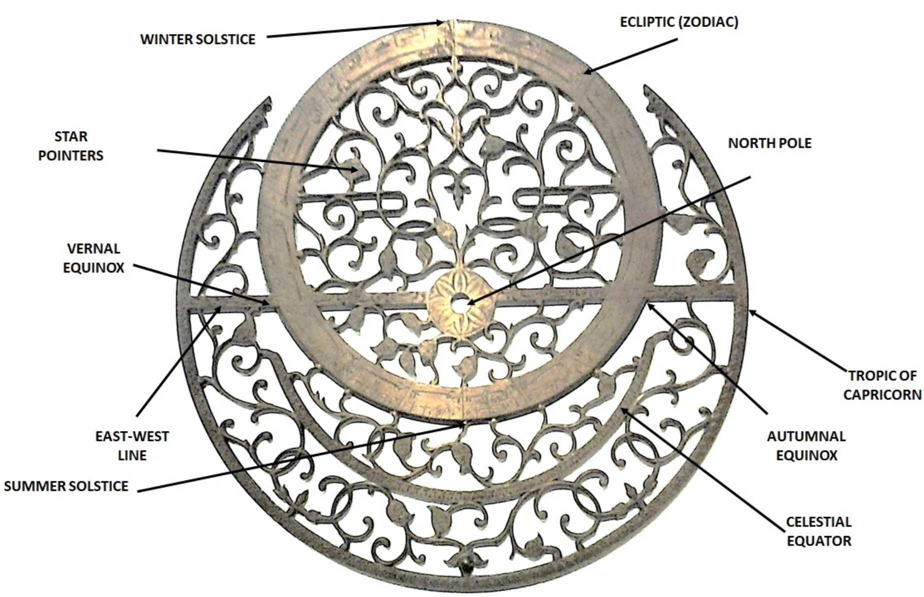

Figure 6: Circles and other elements on the Rete (drawn by Mubashir Ul-Haq Abbasi).

Figure 7: Rete, detail of the upper part (photo by Mubashir Ul-Haq Abbasi).

Figure 8: Rete, detail of the lower part (photo by Mubashir Ul-Haq Abbasi).

ring and east-west bar on the left) proceeding anti-clockwise from Aries to Pisces. Each sign is subdivided into five segments of 6° each and numbered as 6, 12, 18, 24, 30 in *Abjad* notation. The sloped edge of the ecliptic ring is divided into single degrees of arc. The spaces between these rings are filled with a multitude of floral tendrils. The Capricorn ring and the Equator ring are engraved with decorative

Figure 9: Reverse side of the rete, detail (photo by Mubashir Ul-Haq Abbasi).

patterns, while the small ring at the centre is bedecked with a flower of eight petals.

Interestingly, on the reverse side of the rete (Fig. 9) can be seen the Sanskrit names of some zodiac signs (अथ सिंहः, "now Leo"); these signs are divided into 5° each and numbered as 5, 10, 15, 20, 25, 30 in Devanagari numerals. Apparently, on this side a rete was engraved for a Sanskrit astrolabe, but because of some mistake, it was discarded and reused for the present astrolabe.

A small round metallic piece (مدير *mudir*) is affixed on the lower side of the rete to facilitate its rotation.

Figure 10: Engraving on the horizontal bar of the Rete (photo by Mubashir Ul-Haq Abbasi).

On the horizontal bar is engraved a prayer commonly recited by the Muslims of the Shia sect. It reads as follows:

ناد علیا مظهر العجائب تجده عونا لک فی النوایب کل هم و غم سینجلی بنوتک یا
محمد و بولایتک یا علی یا علی بنبوتک یا

nād-i ͨAlī yā mazharal ͨajāyabi tajidhu ͨawnallaka finnawaibi kullu ham wa ghamm sayanjali bi nabuwwatika yā Muḥammad u wa bi wilayatika yā ͨAlī u yā ͨAlī u yā ͨAlī

> Call on ᶜAlī, capable of performing the extraordinary; you will find him effective in all the calamities, worries and sorrows; all the despairs will disappear by thy prophethood O! Muḥammad and by the powers bestowed on you O! ᶜAlī O! ᶜAlī O! ᶜAlī.

To the floral tendrils are attached 23 leaf-shaped star pointers on which the names of stars are engraved. At the tip of each leaf, there is a dot inside a circle; this dot indicates the exact position of the star. The spaces inside each of these small circles appear to have been inlaid with silver. In many cases, besides the star names, a number is engraved in Arabic numerals. These numbers follow the sequence when the stars are arranged according to their right ascensions. Probably the star names and the serial numbers are copied from some astronomical table. Besides the 23 names are engraved on the leaves, 3 more star names are engraved on the ecliptic ring. In the table below, these 26 star names are arranged in the order of their right ascensions.

Table 2: Stars on the Rete of the Astrolabe arranged according to their Right Ascension.

S. No.	Inscribed on Rete	Transliteration	Identification	Common Name
1	سرة الفرس ٣١	*Sirrah al Fars 31*	δ Pegasi = α Andromedae	Alpheratz
2	کف الخضیب٥	*Kaff al-Khaḍīb 5*	β Cassiopeiae	Caph
3	ذنب القیطس جنوبی	*Dhanab al-Qayṭus Janūbī*	β Ceti	Deneb Kaitos, Diphda
4	بطن الحوت٣	*Baṭn al-Ḥūt 3*	β Andromedae	Mirach
5	شرطین	*Sharaṭayn*	β Aries	
6	راس الغول ۶	*Rās al-Ghūl 6*	β Persei	Algol
7	برشاوش	*Barshāwish*	α Persei	Mirfak
8	عین الثور٨	*ᶜAyn al-Thawr 8*	α Tauri	Aldebaran
9	٩ رجل الجوزا	*Rijl al-Jawzā' [al-Yusrā] 9*	β Orionis	Rigel
10	١٠ رجل الیمنیٰ	*Rijl [al-Jawzā'] al-Yumnā10*	κ Orionis	Saiph
11	١١ عیوق	*ᶜAyyūq 11*	α Aurigae	Capella
12	١٢ ید الجوزا الیمنیٰ	*Yad al-Jawza' al- Yumnā 12*	α Orionis	Betelgeuse
13	١۴ شعریٰ یمانی	*Shiᶜrā Yamānī 14*	α Canis Majoris	Sirius
14	مقدم التوامان	*Muqaddam al-Tawāman*	α Geminorum	Castor
15	١٧ قلب الاسد	*Qalb al-Asad 17*	α Leonis	Regulus
16	١۶ جناح الغراب	*Janaḥ al-Ghurāb 16*	α Corvi	Gienah
17	٢٠سماک العزل	*Simāk al- ᶜAzal 20*	α Virginis	Spica
18	٢١ سماک رامح	*Simāk Rāmiḥ 21*	α Bootis	Arcturus
19	نییر الفکه ٢٢	*Nayīr al-Fakkah 22*	α Coronae Borealis	Alphecca

Table 2: Stars on the Rete of the Astrolabe arranged according to their Right Ascension (cont.).

S. No.	Inscribed on Rete	Transliteration	Identification	Common Name
20	راس الحواء۲۴	*Rās al-Ḥawwā 24*	α Ophiuchi	Rasalhague
21	نسر واقع۲۷	*Nasr Wāqi^c 27*	α Lyrae	Vega
22	منقار الدجاجه	*Minqār al-Dajājah*	β Cygni	Albireo
23	۲۸نسر طائر	*Nasr Tā'ir 28*	α Aquilae	Altair
24	ذنب الدجاجه۳۰	*Dhanab al-Dajājah 30*	α Cygni	Deneb
25	۳۹ فم الحوت	*Fam al-Ḥūt 39*	α Pisces	Fomalhut
26	منكب الفرس	*Mankib al-Faras*	β Pegasi	Scheat

THE PLATES

Below the rete are stacked seven plates (صفيحه *ṣafīḥa* [singular], صفائح *ṣafā^cih* [plural]). The first six plates are designed for different terrestrial latitudes. Five of these are calibrated on both sides for use at different geographical latitudes; the sixth one is likewise engraved only on one side, and the reverse is left blank. In these plates there are labels in very large letters in the lower half stating the latitude (العرض *al ^carḍ*) and the duration of the longest day (ساعات *sā^cāt*); the latitude itself is written in very tiny numerals on some plates, but on some others no latitude is mentioned. The value of the longest day is not mentioned on any plate. Of course, the missing latitude can be estimated by counting the almucantar arcs between the oblique horizon and the North Pole and the missing duration of the longest day can be found in one or other Islamic astronomical table (Arabic زيج *zīj*), but their absence on these plates reduces their utility. The seventh plate is engraved on both sides with multiple horizons. All the plates have a small protruding tip below at the north point which goes into the small recess in the rim of the mater and keeps the plate static.

Compared to the excellently crafted mater and rete, the workmanship of these plates is very poor. Apparently, these plates were engraved by some apprentice and not by Pīr Bakhsh himself.

The plates designed for different terrestrial latitudes carry three concentric circles. The outermost circle at the periphery represents Tropic of Capricorn (مدار رآس الجدى *madār rās al-Jadī*), the next circle is the celestial equator (دائرة العتدال *dā'irat al-^catidāl*) and the innermost circle represents the Tropic of Cancer (مدار رآس السرطان *madār rās al-Saraṭān*). On these plates, the horizontal and vertical diameters intersect at the centre which is the North Pole. The vertical line is the meridian (خط وسط السما ء *khaṭṭ wasiṭ al-samā'*) that connects north (at the bottom of the plate) to the south (at the top of the plate) through the pole and the zenith. A part of this line, from the oblique horizon up to the zenith, is called

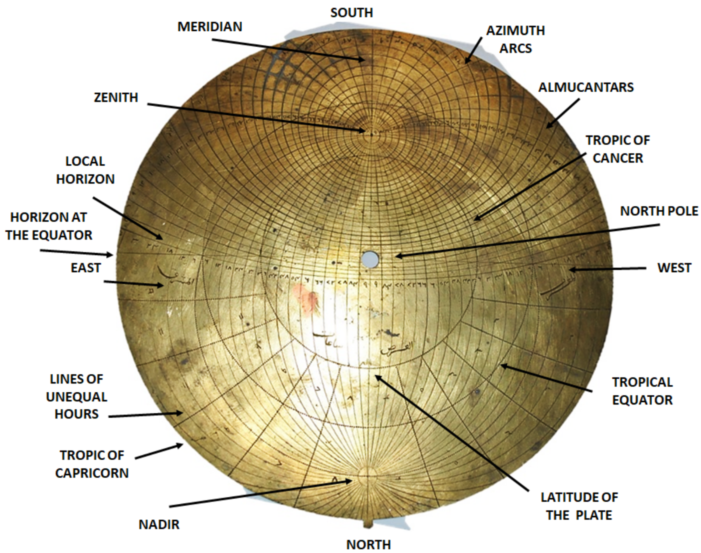

Figure 11: Plate for Latitude of 14°, marked with the circles and other elements (photo by Mubashir Ul-Haq Abbasi)

the midday line (خط نصف النهار *khaṭṭ niṣf al-nahār*). The horizontal line is called east-west line or level horizon (افق الاستواء *ufq al-istawā*). The true or the oblique horizon is marked by an arc below the center. The point where it intersects with the celestial equator on the left is called the "east point" (نقطة المشرق *nuqṭat al-Mashriq*) and where it intersects with the celestial equator on the right carries the name "west point" and (نقطة المغرب *nuqṭat al-Maghrib*). But generally these two points are marked with the labels "east" (المشرق *al-Mashriq*) and "west" (المغرب *al-Maghrib*).

The Almucantars

The term is derived from the Arabic الدائره المقنطره *al-dāirah al muqanṭarah*, meaning a "complete circle." These are drawn parallel to the oblique horizon up to the zenith and show the elevation above the horizon; therefore these are also called altitude circles. Though drawn parallel to the oblique horizon, they appear eccentric on the plate because of stereographic projection. The number of these circles may vary from 90 to any lower number, depending on the size of the plate. An astrolabe is called "complete" (Arabic تام *tāmm*) when there are ninety circles. In this astrolabe there are thirty circles, one for every third degree; therefore it is called "tripartite" (ثلثى *thulthī*). These circles are numbered in Arabic numerals on both sides of the meridian from 3 to 90, starting from the oblique horizon and reaching up to the zenith.

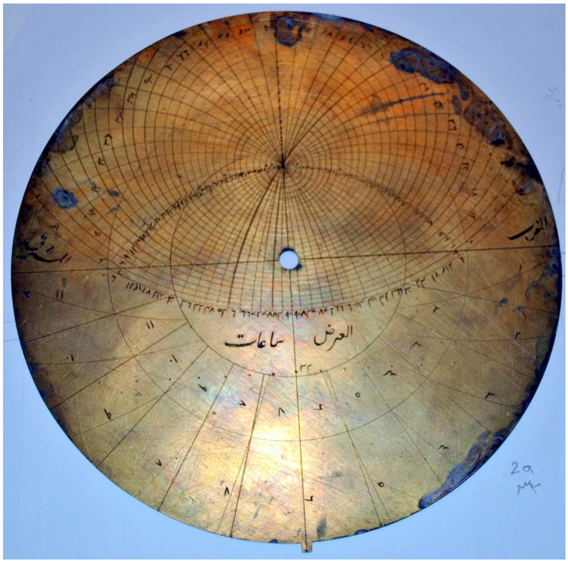

Figure 12: Plate for the Latitude of 32° (photo by Mubashir Ul-Haq Abbasi)

The Azimuth Arcs

The term azimuth is derived from the Arabic word السمت (*al-samt*) meaning "direction" (plural السموت *al-sumūt*). The azimuths are the great circles passing through the zenith and nadir, crossing the horizon at right angles. On most of the plates they are drawn above and below the oblique horizon. On plate 3, however, they are drawn above the oblique horizon. The azimuths are numbered from the east and west points up to the meridian at an interval of six degrees.

The Hour Lines

Today we use equal hours in our daily life, dividing the time from midnight to the next midnight in twenty-four equal units. But in the Middle Ages, the entire period of daylight was divided into twelve parts and the period of night was likewise divided into 12 parts. Since the duration of the daylight and night vary according to seasons, their divisions are called unequal hours. These are counted from the western horizon (i.e., from the sunset) up to the eastern horizon and are useful for indicating the times of the Islamic prayers. On the present astrolabe, however, these lines for the unequal hours are not drawn on all the plates, while the lines of equal hours are shown on all plates. These are numbered from the western horizon.

The space below the oblique horizon generally contains information about the latitude for which the plate is designed (العرض *al-^{c}arḍ*) and the corresponding duration of the longest day in hours at this latitude (' ساعات *sā ^{c}āt*).

Figure 13: Horizon Plate, Side b (photo by Mubashir Ul-Haq Abbasi).

The Plate of Horizons

The astrolabes made by the Lahore Family of Astrolabists contain invariably a plate one side of which is designed as the plate of Ecliptic Coordinates (صفيحة ميزان العنكبوت *ṣafīḥat mīzān al-ᶜankabūt*) and the other side as the plate of horizons (صفيحه الآفاقى *ṣafīḥa al-āfāqī*). But in all his astrolabes, Bulhomal engraves multiple horizons on both sides of the plate and ignores the Ecliptic Coordinates. The same is the case with the seventh plate in the present astrolabe; here both sides are engraved with multiple horizons.

The plate of horizons (Fig. 13) is useful for ascertaining the times of sunrise and sunset, the day length and the rising times of certain stars, at geographical latitudes for which no provision is made in the astrolabe concerned. For this purpose, a large number of horizons (Arabic افق *ufq*, plural آفاق *āfāq*) are drawn on this plate. In order to accommodate many horizons, only half horizons are drawn at convenient intervals. They are arranged in four sets in the four quadrants of the plate. The latitude of each arc of horizon is marked where it begins near the circumference and where it ends at one of the diameters.

Like the latitude plates, the horizon plate also carries three concentric circles, representing the Tropic of Capricorn, the Celestial Equator, and the Tropic of Cancer. The plate is divided into four quadrants. In each quadrant a group of horizon arcs are so plotted that they commence at the outer circle of the Tropic of Capricorn, merge together as they cross the circle of equator and spread apart as they reach the opposite half diameter. The latitude for each horizon is written at both the ends, namely at the half diameter and again close to the Tropic of

Cancer, in Arabic numerals. On the front side of the present plate, in the first quadrant are plotted eleven arcs with intervals of 8 degrees from 3 to 83, in the second from 5 to 85, in the third 7 to 87 and in the fourth from 9 to 89 — in other words, all latitudes with odd numbers. On the reverse side, there is a similar arrangement: in the first quadrant from 4 to 84, in the second from 6 to 86, in the third 8 to 88 and in the fourth from 10 to 90, thus all the latitudes with even numbers.

Table 3: The Plates of the Astrolabe.

Plate	Latitude in degrees	Longest day in hours	Azimuth arcs at 6° intervals	Unequal Hour lines	Equal hour lines
1a	14	Not given	Above and below the oblique horizon	No	Counted from the western horizon
1b	Blank		Only the circles of the Equator and the Tropic of Cancer are drawn		
2a	20	Not given	Above and below the oblique horizon	No	Counted from the western horizon
2b	[27]	Not given	Above and below the oblique horizon	No	Counted from the western horizon
3a	25	Not given	Above the oblique horizon	Yes	Counted from the western horizon
3b	32	Not given	Above the oblique horizon	Yes	Counted from the western horizon
4a	33	Not given	Above and below the oblique horizon	No	Counted from the western horizon
4b	[39]	Not given	Above and below the oblique horizon	No	Counted from the western horizon
5a	[45]	Not given	Above and below the oblique horizon	No	Counted from the western horizon
5b	50	Not given	Above and below the oblique horizon	No	Counted from the western horizon

Table 3: The Plates of the Astrolabe (cont.).

Plate	Latitude in degrees	Longest day in hours	Azimuth arcs at 6° intervals	Unequal Hour lines	Equal hour lines
6a	56	Not given	Above and below the oblique horizon	No	Counted from the western horizon
6b	62	Not given	Above and below the oblique horizon	No	Counted from the western horizon
7a	Plate of Horizons for latitudes 3, 5, 7, 9 ... 89				
7b	Plate of Horizons for latitudes 6, 8, 10, 12 ... 90.				

THE GEOGRAPHICAL GAZETTEER

Of the seven astrolabes that are signed by Bulhomal or attributable to him for stylistic reasons, only one astrolabe carries a geographical gazetteer on the inner side of the mater, providing the names of cities (*al-bilād*), longitudes (*al-ṭūl*) and latitudes (*al-*ᶜ*arḍ*) for some 57 localities.[19] The same gazetteer is engraved here on the present astrolabe, minus three localities. However, there occurred a very grave error in the argument, where *iqlīm* is engraved in the place of *al-bilād*, not once but five times. In Greek antiquity, the inhabited part of the earth is called oecumene which extended northwards from the equator up to roughly the latitude 50° 30′ N. This area is divided into seven stripes which are called in Greek "clima" (in singular, "climata", plural). It is this "clima" which became *iqlīm* in Arabic.[20] Therefore, *iqlīm* has nothing to do with the names of localities. It is a mystery how such a serious error could occur on this astrolabe!

While latitudes are counted from the equator, up to the North Pole or the South Pole, in these astrolabes, longitudes are measured not from Greenwich, but from the Fortunate Islands (*al-Jazā'ir al-Khalidāt*) in the Atlantic, roughly 35° west of Greenwich.

On the entire surface inside the rim are drawn several concentric circles; eight diameters passing through the centre divide the surface into 16 segments. In one of these segments is written the argument (*iqlīm*, *ṭūl*, ᶜ*arḍ*) five times one below the other (see Figure 12). The other 15 segments are filled with the names of the

19 Sarma 2021: B022. The same gazetteer is engraved in two astrolabes by Bulhomal's pupil Ghulām Qādir Kapūrthalī, see Sarma 2021: B027 and B028.

20 Sarma 2021: 58–59.

Figure 14: Geographical Gazetteer on the inner side of the Mater (photo by Mubashir Ul-Haq Abbasi)

Figure 15: The Argument of the Gazetteer (photo by Mubashir Ul-Haq Abbasi).

cities and their longitudes and latitudes. The cities are not listed by the order of their latitudes, but according to increasing longitudes, with minor variations. The geographical coordinates are given in Arabic numerals. The inclusion of London and Calcutta in the gazetteer gives it a modern touch.

Table 4: Geographical Gazetteer.

S. No.	*al-bilād* Cities	طول *Ṭūl* (Long)	عرض *'Arḍ* (Lat)	Transliteration	Modern Name
Annulus 1					
1	اسکندریه	61;54	30;58	Iskandarya	Alexandria, Egypt
2	مدینة الحکما	65;40	37;20	Madīna al- Hikmā	Athens, Greece
3	مدینة الرسول	75;20	25;0	Madīna al-Rasūl	Medina, Saudi Arabia
4	مکہ معظم	77;10	21;40	Mecca Muᶜ azzam	Mecca, Saudi Arabia
5	بصره	84;0	30;0	Baṣrah	Basra, Iraq
6	بلخ	85;20	46;30	Balkh	Balkh, Afghanistan
7	اصفهان	86;4	32;25	Iṣfahān	Esfahan, Iran
8	شیراز	88;0	29;36	Shīrāz	Shiraz, Iran
9	هرمز	91;0	25;0	Hurmuz	Hormuz, Iran
10	تون	94;30	34;30	Tūn	Tun, Iran
11	هراة	94;4	34;30	Herāt	Herat, Afghanistan
12	بخارا	97;30	39;50	Bukhārā	Bukhara, Uzbekistan
13	سمرقند	99;36	39;37	Samarqand	Samarqand, Uzbekistan
14	دولت آباد	101;30	20;30	Dawlatābad	Daulatabad, India
15	اجین	102; 0	22;30	Ujjain	Ujjain, India
Annulus 2					
16	مانسر	102;25	30;10	Mānsar	Manesar, India
17	بدخشان	104;24	37;10	Badakshān	Faizabad, Afghanistan
18	کابل	104;40	34;30	Kābul	Kabul, Afghanistan
19	نور پور	105;15	31;4	Nūrpur	Nurpur, India
20	پنجا پور	105;35	20; 0	Panjāpur	Bijapur, India
21	قنوج	105;55	26;50	Qanūj	Kannauj, India
22	سومناتهہ	106;10	12; 0	Somnāth	Somnath, India
23	کاشغر	106;30	44;0	Kāshghar	Kashgar, China
24	اورنگ آباد	107;27	20;30	Awrangābād	Aurangabad, India
25	ملتان	107;35	29;40	Multān	Multan, Pakistan
26	قندها ر	107;40	33;0	Qandahār	Qandhar, Afghanistan
27	اودھ	108;6	22;22	Awadh	Awadh, India
28	احمد آباد	108;40	23;55	Aḥmadābad	Ahmedabad, India
29	کشمیر	108;45	35; 0	Kashmir	Srinagar, India
30	گوالیار	109; 0	26;29	Gawaliyār	Gwalior, India
Annulus 3					
31	سیالکوت	109; 0	33;30	Siālkūt	Sialkot, Pakistan
32	برهانپور	109;20	20;31	Burhānpur	Berhampur, India

Table 4: Geographical Gazetteer (cont.).

S. No.	*al-bilād* Cities	طول *Ṭūl* (Long)	عرض *'Arḍ* (Lat)	Transliteration	Modern Name
33	لاہور	109;20	31;50	Lāhore	Lahore, Pakistan
34	تبت	110;3	40;15	Tibbat	Tibet (Lhasa)
35	دهلی	113;35	28;29	Dehlī	Delhi, India
36	متهرا	114;20	27;0	Mathurā	Mathura, India
37	بنارس	117;20	26;55	Banaras	Varanasi, India
38	جونپور	119;6	26;36	Jawnpūr	Jaunpur, India
39	سرنديپ	140;0	10;0	Sarandīp	Colombo, Sri Lanka
40	لندن	170;0	52;0	Landan	London, England
41	نكر كوت	110;0	33;30	Nakar Kut	Nagarkot, Nepal
42	پشاور	106;?	35;	Peshāwar	Peshawar, Pakistan
43	پند دادن خان	108;5	33;30	Pind Dādan Khan	Pind Dadan Khan, Pakistan
44	رامنكر	108;30	32;30	Rāmnakar	Ramnagar, India
Annulus 4					
45	انبرت سر	109;40	31;45	Anbratsar	Amritsar, India
46	لودبيانه	111;0	31;30	Lūdhiyānah	Ludhiana, India
47	انباله	111;50	31;0	Anbālah	Ambala, India
48	بر دوار كنكاچے	113;5	31;0	Hardwār KaṅKājī	Haridwar [on the banks of the] holy Ganga, India
49	نجيب آباد	113;15	31;0	Najībābād	Najibabad, India
50	فرح آباد	113;45	31;0	Farhābād	Farha Abad, Iran
51	لكہنو	114;10	27;0	Lakhnaw	Lucknow, India
52	گيا	14;0	24;0	Gayā	Gaya, India
53	كلكته	124;5	20;20	Kalkatah	Kolkata, India
54	جكن ناتہہ	124;0	20;0	Jagan Nāth	Puri Jagannath, India

THE BACK OF THE ASTROLABE

On the back of the astrolabe (ظهر الاصطرلاب *ẓahr al-asṭurlāb*), the rim of the circular plate is engraved with two concentric scales. The inner scale is divided into single degrees of arc; in the outer scale groups of 6° are numbered in *Abjad* notation, separately for each quadrant. In the upper half the numbers start at the east and west points and reach up to the south point at the top, and thus form the altitude scales. In the lower right quadrant, the numbers commence at the west point proceed up to the north point at the bottom, while in the lower left quadrant they start at the north point and reach up to the east point on the left.

Figure 16: Back of the Astrolabe (photo by Mubashir Ul-Haq Abbasi).

On the back of Bulhomal's two Indo-Persian astrolabes,[21] the upper right quadrant is filled with a sine-cosine grid without any labels and the other three quadrants are left blank. On the back of his two Sanskrit astrolabes,[22] however, the upper right quadrant is filled with a sine-cosine grid with special markings, and the other quadrants are filled with diverse astrological tables. The very same pattern is followed in the present astrolabe with some more additional features.

The Upper Right Quadrant

A sine quadrant (ربع المجیب *rub^{c} al-mujayyab*) is engraved on the upper right (Fig. 17). As mentioned above, the rim is engraved with altitude scales. On the quadrant proper is drawn a grid with 15 horizontal and 15 vertical parallel lines. The complete quadrant represents number 30, as marked from right to left and bottom to top in *Abjad*, from 0 to 30 at an interval of 2. These values are inscribed in the reverse direction as well. The cells in the middle of the quadrant also have these numbers from 0 to 28, written vertically and horizontally. This facilitates reading the values of trigonometric functions directly without counting each cell.[23] By directing the alidade towards the heavenly body, the angle of altitude is read off from the altitude scale on the rim.

21 Sarma 2021: B021 and B022.

22 Sarma 2021: C028 and C029.

23 A similar manner of writing the values in one more vertical row and one horizontal row in the middle of the quadrant appears to be a characteristic feature of Bulhomal's work. This can be seen also in some other instruments of Bulhomal (Sarma 2021: C028, C029, L006) and also in several contemporary instruments (Sarma 2021: K015, K016, L024, U004, U006, U007).

Figure 17: Upper Right Quadrant on the Back (photo by Mubashir Ul-Haq Abbasi)

To find the Sine of this angle, the vertical graduations (cells) are counted and divided by the total length of the scale which is 30. For example, Sin (60) will be found by putting the alidade at "60=س" and the vertical scale reads "26=كو." Now 26 divided by 30 gives Sin (60) = 0.866, which is the answer. The Cosine value of this angle will be read on the horizontal scale. It is a value between "14=يد" and "16=يو"; taken as 15 and then divided by main scale 30, giving Cos (60) = 0.5.

Thus with the help of the alidade the angle of altitude, i.e., the angle of elevation from the horizon, of a heavenly body is measured and also the sine and cosine of that angle. This is the observational function of the astrolabe.

The Upper Left Quadrant

The upper left quadrant (Fig. 18) is filled with a complex astrological table, the two parts of which are engraved one below the other.[24] In the third and fifth rows, because of the absence of adequate space, the names of planets are shown in abbreviations. Thus the sun (شمس) is indicated by (س), the moon (قمر) by (ر), Mars (مريخ) by (ح), Mercury (عطارد) by (د), Jupiter (مشترى) by (ى), Venus (زهره) by (ه) and Saturn (زحل) by (ل). In the table below, we write the full names in English.

24 A similar table is engraved on the back of the Sanskrit astrolabe that is attributable to Bulhomal, see Sarma 2021: C028.

Figure 18: Upper Left Quadrant on the Back (photo by Mubashir Ul-Haq Abbasi).

Table 5: Astrological Table.

1	*Mirrikh* Mars	*Zuhrah* Venus	*ᶜAuṭārad* Mercury	*Qamar* Moon	*Shams* Sun	*ᶜAuṭārad* Mercury
2	***Ḥamal*** Aries	***Thawr*** Taurus	***Jawjāh*** Gemini	***Saraṭān*** Cancer	***Asad*** Leo	***Musalsalah*** Virgo
3	Jupiter Venus Mercury Mars Saturn	Venus Mercury Jupiter Saturn Mars	Mercury Jupiter Venus Mars Saturn	Mars Venus Mercury Jupiter Saturn	Jupiter Venus Saturn Mercury Mars	Mercury Venus Jupiter Mars Saturn
4	6 6 8 5 5	8 7 8 5 2	6 6 5 7 6	7 6 6 7 4	6 5 7 6 6	7 10 4 7 2
5	Mars Sun Venus	Mercury Moon Saturn	Jupiter Mars Sun	Venus Mercury Moon	Saturn Jupiter Mars	Sun Venus Mercury
1	*Zuhrah* Venus	*Mirrikh* Mars	*Mushtarī* Jupiter	*Zuḥal* Saturn	*Zuḥal* Saturn	*Mushtarī* Jupiter
2	***Mīzān*** **Libra**	***ᶜAqrab*** **Scorpio**	***Qaws*** **Sagittarius**	***Zady*** **Capricornus**	***Dalw*** **Aquarius**	***Ḥūt*** **Pisces**
3	Saturn Mercury Jupiter Venus Mars	Mars Venus Mercury Jupiter Saturn	Jupiter Venus Mercury Saturn Mars	Mercury Jupiter Venus Saturn Mars	Mercury Venus Jupiter Mars Saturn	Venus Jupiter Mercury Mars Saturn
4	6 8 7 7 2	7 4 8 5 6	12 5 4 5 4	7 7 8 4 4	7 6 7 5 5	12 4 3 9 2
5	Moon Saturn Jupiter	Mars Sun Venus	Mercury Moon Saturn	Jupiter Mars Sun	Venus Mercury Moon	Saturn Jupiter Mars

Table 6: Regents of the Zodiac Signs.

	Sign	Regent		Sign	Regent
1	Aries	Mars	7	Libra	Venus
2	Taurus	Venus	8	Scorpio	Mars
3	Gemini	Mercury	9	Saggitarius	Jupiter
4	Cancer	Moon	10	Capricorn	Saturn
5	Leo	Sun	11	Aquarius	Saturn
6	Virgo	Mercury	12	Pisces	Jupiter

Table 7: Regents of the Decans.

Sign	Regents of Decan 1	Regents of Decan 2	Regents of Decan 3
Aries	Mars	Sun	Venus
Taurus	Mercury	Moon	Saturn
Gemini	Jupiter	Mars	Sun
Cancer	Venus	Mercury	Moon
Leo	Saturn	Jupiter	Mars
Virgo	Sun	Venus	Mercury
Libra	Moon	Saturn	Jupiter
Scorpio	Mars	Sun	Venus
Sagittarius	Mercury	Moon	Saturn
Capricorn	Jupiter	Mars	Sun
Aquarius	Venus	Mercury	Moon
Pisces	Saturn	Jupiter	Mars

In this composite table are included three different astrological tables, namely (a) Regents of the zodiac signs (Table 6), (b) Limits of the zodiac signs (Table 8), and (c) Regents of the Decans (Table 7). Rows two and one constitute the Table of Signs and their Regents as shown below.

Rows two and five form the table of the regents of the decans. A decan (*wujūh* singular, *wajah* plural) is one-third part of a sign and is equal to 10 degrees. These decans have their own regents.

Thirdly, rows two, three and four constitute the Tables of the Limits or Terms of the Zodiac Signs. In this system, the 30 degrees of arc of each Sign is divided into five intervals of varying length. These intervals are called *ḥudūd* (limit or term) and are assigned to the five planets other than the Sun and the Moon. However, the order of the planets and the intervals assigned to them is different for each sign. But the total number of degrees in each row amounts in all cases to 30.

Figure 19: Lower Half of the Back (photo by Mubashir Ul-Haq Abbasi).

Table 8: Limits of the Zodiac Signs.

Aries	Jupiter 6	Venus 6	Mercury 8	Mars 5	Saturn 5
Taurus	Venus 8	Mercury 7	Jupiter 8	Saturn 5	Mars 2
Gemini	Mercury 6	Jupiter 6	Venus 5	Mars 7	Saturn 6
Cancer	Mars 7	Venus 6	Mercury 6	Jupiter 7	Saturn 4
Leo	Jupiter 6	Venus 5	Saturn 7	Mercury 6	Mars 6
Virgo	Mercury 7	Venus 10	Jupiter 4	Mars 7	Saturn 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 5	Mars 4
Capricorn	Mercury 7	Jupiter 7	Venus 8	Saturn 4	Mars 4
Aquarius	Mercury 7	Venus 6	Jupiter 7	Mars 5	Saturn 5
Pisces	Venus 12	Jupiter 4	Mercury 3	Mars 9	Saturn 2

Lower Left Quadrant

Here the names of zodiac signs arranged in four concentric rows and three columns. The names are written in a zigzag manner, i.e., in the first row from right to left, in the second row from left to right, in the third row from right to left and in the fourth row from left to right. Here, the zodiac signs in each column have the same rising times at the equator.

Table 9: Rising Times of the Zodiac Signs at the Equator.

Gemini	Taurus	Aries
Cancer	Leo	Virgo
Sagittarius	Scorpio	Libra
Capricorn	Aquarius	Pisces

Shadow Squares

In the lower half, shadow squares are arranged on either side of the vertical line. In the shadow square on the right, both the vertical and horizontal scales are divided into seven units. The shadow square on the left has twelve divisions each on vertical and horizontal scales. The divisions on both sides are numbered in Arabic numerals, on the horizontal scales from the centre to the right and to the left, and on the vertical scales from the top to the bottom.

On the right, the horizontal scale is called ظلاقداممستوی *ẓill aqdām mustawī* (umbra recta, or direct shadow, in feet), i.e., shadow thrown by a vertical gnomon on a horizontal plane. The vertical scale on the right is called ظل اقدام معکوس *ẓill aqdām ma^{c}kūs* (umbra versa, or reverse shadow, in feet), i.e., shadow thrown by a horizontal gnomon on a vertical plane. On the left, the horizontal scale is called ظل اصابعی مستوی *zill aṣābi^{c} mustawī* (umbra recta, or direct shadow, in digits) the vertical scale ظل اصابعی معکوس *zill aṣābi^{c} ma^{c}kūs* (umbra versa, or reverse shadow, digits). But these labels are not engraved on the present astrolabe.

In Greece, the height of the average human was taken as equal to seven of his feet, leading to the practice of dividing any gnomon into seven parts and using the term "feet" (Arabic قدم *qadam*, plural اقدام *aqdām*) to refer to the divisions. The twelve divisions of a gnomon of given length have their origin in the Babylonian observation that a finger held at arm's length obscured 1/12 of a degree of the night sky. The term "fingers" (Arabic اصبع *aṣba^{c}*, plural اصابع *aṣābia^{c}*) refers to this division.[25]

These shadow squares are useful in land survey for measuring the distances or heights of certain prominent landmarks.

Table of Angles and their Cotangents

Inside the shadow squares, three groups of lines radiating from the central hole are dawn and filled with Arabic numerals which are arranged in the form of tables. The table on the upper left has six columns and four rows. The table in the middle is spread on both sides of the meridian line. The left half has six columns and four rows, while the right half has six columns and three rows. The table on the upper right is largely covered by the Sine quadrant.

25 Gibbs and Saliba 1984: 226.

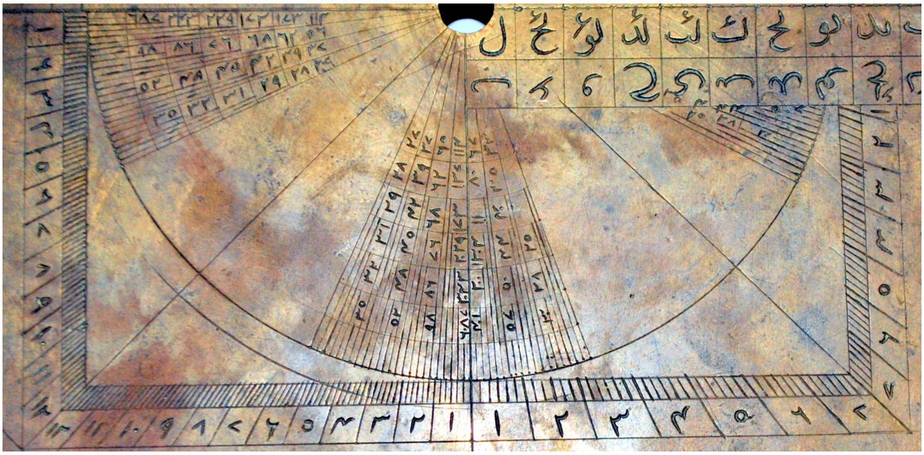

Figure 20: Table of Angles and their Cotangents (photo by Mubashir Ul-Haq Abbasi)

This arrangement of radiating lines and numbers occurs on no other instrument but here; therefore it is an entirely new innovation by Bulhomal. Professor Jan P. Hogendijk has kindly provided an explanation.[26] According to him, these numbers relate to the angular lines (representing the angles) and their cotangents. The table should be viewed as being composed of two smaller tables: the left one for the 12-divisions and the one on the right for the 7-divisions. Cotangent values inscribed in the tabular form give a direct answer to the length of the shadow for *aqdām* (7 feet or 7 units of length) or *aṣabi*^{c} (12 fingers or 12 units of length). Therefore, the left part of the table gives, directly, the length of the shadow for a gnomon of twelve units when the angle of the Sun is between 1 degree and 24 degrees. Similar arrangement can be seen on the right part of the table for a gnomon of 7 units.

This table as inscribed on the astrolabe shows rounded off values of the cotangents. There are some minor errors where the engraver mistook a dot on the written table for zero; the correct values are shown in italics in brackets next to the engraved values.

26 Hogendijk 2018.

Table 10: Upper Left Table.

Values =12 × Cot (angle); Angles = 1 to 24 degrees						
Value	687	243	229	172	173	114
Angle	1	2	3	4	5	6
Value	98	86	76	68	62	56
Angle	7	8	9	10	11	12
Value	52	48	45	42	39	37
Angle	13	14	15	16	17	18
Value	35	32	31	29	28	26
Angle	19	20	21	22	23	24

Table 11: Middle Table Left Half.

Middle part and right-middle part of the table, separated by the vertical line.

Values =12 × Cot (angle); Angles = 19 to 24; 13 to 18; 1 to 6						
Value	35	32	31	29	28	27
Angle	19	20	21	22	23	24
Value	52	48	45	42	39	37
Angle	13	14	15	16	17	18
Value	6087 (*687*)	3043 (*343*)	2029 (*229*)	173	137	114
Angle	1	2	3	4	5	6

Table 12: Middle Table Right Half.

Values = 7 × Cot (angle); angles are from 1 to 15						
Value	401	200	1304 (*133*)	11 (*100*)	80	67
Angle	1	2	3	4	5	6
Value	57	50	44	40	35 (*36*)	33
Angle	7	8	9	10	11	12
Value	30	28	25 (*26*)			
Angle	13	14	15			

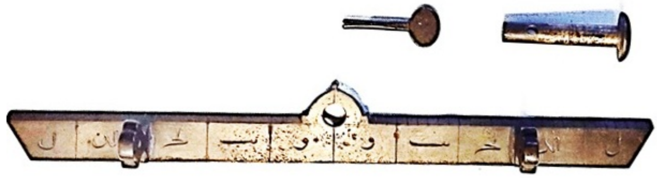

Figure 21: Alidade, Pin and Wedge (photo by Mubashir Ul-Haq Abbasi).

Table 13: Upper Right Table.

Values = 7 × Cot (angle); angles are 9, 10, 13, 14, 15 degrees			
Value	4 (*40*)	44	
Angle	10	9	
Value	25 (*26*)	28	30
Angle	15	14	13

Alidade, Pin and Wedge

The alidade (العضاده: *al-ᶜidādah*) is 216 mm long and 17 mm wide; it is divided into twelve equal parts, six on each half and numbered in *Abjad* from the centre towards both ends as 6, 12 ,18, 24, 30. At the two ends of the alidade are affixed two sighting plates in a plane perpendicular to that of the alidade. There is one hole in each of the sighting plates. They are shaped like tulips in outline.[27] Like the leaf-shaped star pointers, the tulip-shaped sighting plates is another characteristic feature of Bulhomal's astrolabes. The pin (قطب *qutb*) and wedge (فرس *faras*) of this astrolabe are simple in design.

The Persian inscription on the thick edge of the astrolabe

On the thick edge of the astrolabe is a long inscription in two lines, which are separated by a thick band. The letters are engraved in high relief against a hatched background. The inscription reads as follows:

> این اصطرلاب پیے شمالے مشعر بر جمیع احکامات اصطرلاب و ربع المجیب
> بر ہدایت عضاده واعداد الارتفاع و طبقات العروض و صفحہ افاق و العنکبوت
> الاعداد نصف القطرین و الظلین معکوسین ومستوین ظل سلم و خطوط جبین
> السہمین و مخبر بر اخبارات نجوم حدود و مثلثات و غیره و حاوی بر امورات
> عرض یعنی عرض و طول بلد بہ تجویز علامہ الدہر جامع العلوم صوری و معنوے
> منبع الاختراعات و الصناعات وحید النظم فرید البشر صاحب السیف و القلم

27 Sarma 2021: see Figs. B022.7 and C028.4.

Figure 22: Inscription engraved on the thick edge (photo by Mubashir Ul-Haq Abbasi)

مولوی غلام محمد خان غلامی علامے أصلح الله شأنه بحسن اہتمام رئیس منجمین
قدوة المہندسین مقتدای اہل صنعت سر معشر اصحاب ہئیات مجموعه کمالات
واقف حقائق کواکب و دقائق عقده کشای ما لا ینحل فرد اکمل وجود مکمل

لاله بلہومل لاہوری در دارالریاست کپور تهل برائے برخوردار سعادت آثار مبارک
علی خان طال الله عمره و ارزقه علما نافعا مصنوع و مزیّن شد سمت ١٨٩٧ بیری
سنه ١٢٥٧ هجری سنه ١٨٤١ عیسوی

īn uṣṭurlāb pai shumālī mush^{c}ir bar jamī^c aḥkāmāt-i uṣṭurlāb wa rub^c al-mujayyab bar hidāyat ^{c}idāda wa a^{c}adād al-irtafā^c wa ṭabqāt al-^{c}urūd wa ṣafḥa-yi āfāq wa al-^{c}ankabūt wa al-^{c}adād niṣf al-quṭrayn al-ẓillain m^{c}akusayn wa mustavayn ẓill sullam wa khuṭūt-i jaybayn al-sahmayn wa mukhbir bar akhbārāt nujūm ḥadūd wa muthallathāt wa ghayruhu wa ḥāvī bar umūrāt ^{c}arḍ y^{c}anā ^{c}arḍ wa ṭūl balad bi tajvīz ^{c}allāma al-dahar jāmi ^{c}al-^{c}ulūm-i ṣūrī wa m^{c}anawī manb^{c}a al-ikhtirā^{c}āt wa al-ṣinā^{c}āt wahīd al-naẓm farīd al-bashar ṣāhib al-sayf wa al-qalam mawlwī Ghulām Muḥammad Khān Ghulāmī ^{c}allāmay aṣlaḥ Allāh shʾāna-hu bi-ḥusn-i ihtimām raʾīs munajjimīn qudwat al-muhandisīn muqtadāi ahl-i ṣan^{c}at sar m^{c}ashar-i aṣḥāb-i hayʾa majmū^{c}a-yie kamalāt wāqif-i ḥaqāʾiq-i kawākib wa daqāiq ^{c}uqdah kusha-yi lā yanḥal fard akmal wajud mukamal Lālah Balhūmal Lāhorī dar riyāsat Kapurthal barāy barkhurdār sa^{c}ādat āthār Mubārak ^{c}Alī Khān ṭāl Allāh ^{c}umrahu wa rizqahu wa ^{c}ilman nafi^{c}an masnū^c wa mūzayyan shud Samvat sanah 1897 bairi (sic) *sanah 1257 Hijrī sanah 1841 ^{c}Īsvī.*

This astrolabe for the northern hemisphere (شمالے *shumāli*) has been made according to all the rules (احکامات *aḥkāmāt*) of the astrolabe (اصطرلاب *uṣṭurlāb*) and the sine quadrant (ربع المجیب *rub^c al-mujayyab*), as per the instructions (ہدایت *hidayat*) [of the gentleman to be mentioned below]: the alidade (اعضاده *^{c}idādah*) and the numbers (اعداد *ᶜadād*) [i.e., the graduations of the scales of] altitude (الارتفاع), and the plates of latitudes (طبقات العروض , *ṭabqāt al-ᶜurūd* ?), and the plate of horizons (صفحه افاقى *ṣafīḥa āfāqī*), and the rete (العنكبوت *al-ᶜankabūt*), and the numbers (العداد *al-ᶜadād*) [i.e., the graduations of the scales] of the radii (نصف القطرين *niṣf alqaṭrain*), and [the graduations of the scales] of the reverse and direct shadows in the shadow squares (الاعداد نصف القطرين و الظلين ,معكوسين ومستوين ظل سلم *al-ᶜadād niṣf al-quṭrayn al-ẓillain mᶜakusayn wa mustavayn ẓill sullum*), and the lines of sines [and] versed sines (السهمين خطوط جيبين *khaṭūt jaybayn alsahmayn*), and information (مخبر *mukhbir*) of the astrological matters (اخبارات نجوم *akhbarat najūm*) [such as] the limits (حدود *ḥudūd*), trigons (مثلثات *muthallathāt*) and similar things (و غيره *waghera*); it covers all the matters (حاوى بر امورات *ḥavī bar umūrat*) of latitudebeginfig();*ᶜard*), namely (يعنى *yᶜanī*) the latitude(s) and longitude(s) of citi(s) (طول بلد عرض *ᶜard ṭūl balad*);

on the suggestion of (به تجويز *bah tajvīz*) the scholar of this era (علامه الدہر *ᶜallama aldahar*), who is an icon of the knowledge (جامع العلوم *jamiᶜ al-ᶜulūm*) of the visible and invisible [i.e., factual and spiritual] (صوري و معنوے *ṣūrī wa mᶜanavī*), the source of innovations (منبع الاختراعات *manbaᶜ alikhtrāᶜt*) in industrial products (الصناعات *al-ṣanāᶜt*), a unique administrator (وحيد النظم *wahīd alnazm*), an exceptional person (فريد البشر *farīd albashar*), the master of the sword and pen (صاحب السيف القلم *ṣāhib al-sayf al-qalam*), **Mawlwī Ghulām Muḥammad Khān Ghulāmī ᶜAllāmay**, with the blessing of Allah (اصلح الله شانه *aṣlaḥ Allah shānahu*),

with the beauty of (بحسن *bi-ḥusn-i*) of the efforts (ابتمام *ihtamām*) of the leader of astrologers (رئيس منجمين *raīs munajjamīn*), the chief of engineers (قدوه المهندسين *qadvah al-muhandasīn*), the front-runner of technologists (مقتدائى اہل صنعت *muqtadai ahl ṣanaᶜt*), the head of the community of astronomers (سر معشر اصحاب ہئيات *sar maᶜshar aṣḥāb haiāt*), an encyclopedia of diverse knowledge (مجموعه كمالات *majmoᶜe kamalat*), a thorough knower of the nature of the stars (واقف حقائق كواكب *wāqif ḥaqāiq kawākib*), a solver of difficult and tedious problems (عقده كشائى لا ينحل *u'qdah gushay-i lā yanḥal*), a perfect person (فرد اكمل), a perfectionist (مكمل *mukmal*), **Lālah Bulhomal Lāhūrī**, in the capital of the state of Kapurthala

for the young promising **Mubārak ᶜAlī Khān** — may he have a long life and seek beneficial knowledge —

fabricated (مصنوع *maṣnūᶜ*) and decorated to perfection (مزين شد

mūzayyan shud) [in] Samvat year 1897 bairi (sic), Hijrī year 1257, Christian year 1841.

This inscription first enumerates the components of the astrolabe and then goes on to describe, in flamboyant terms, the individuals who commissioned the astrolabe, who designed it and for whom it was made. The enumeration of the components of the astrolabe, especially of the items on the back, is somewhat haphazard. It commences with the alidade and the altitude scales on the rim of the back, then mentions the latitude plates, the horizon plate, and the rete. Thereafter come successively the numbers of the radii, reverse and direct shadows, and the lines of sines and versed signs; the correct order ought to be the numbers (i.e., graduations on the scales) of the radii and the lines of sines and versed sines, and then the reverse and direct shadows. This is followed by astrological data, namely the limits and trigons (there is a table of limits, but there is no table of trigons on the back). Finally, at the end are mentioned the latitudes, longitudes, and the names of cities (which make up the geographical gazetteer); these should have been mentioned after the horizon plate.

The Date of Manufacture

The inscription is dated in three eras: Vikrama Saṃvat 1897, Hijrī 1257 and Christian 1841. The Saṃvat year 1897 commences on 11 April 1840 and concludes on 10 April 1841; the Hijrī year 1257 starts on 22 February 1841 and ends on 10 February 1842. Therefore, the astrolabe was completed between 22 February and 10 April 1841.

The Individuals associated with this Astrolabe

The name of Mawlwī Ghulām Muḥammd is mentioned by Lepel H. Griffin in his book, *The Rajas of the Punjab*.[28] Ghulām Muḥammd was an important member of the Ahlūwālia court at Kapurthala and was sent as an emissary to the British government officials at Lahore. This astrolabe mentions him as a literary figure and a soldier. The astrolabe was made for Mubārak ᶜAlī Khān, who was apparently a young person; the prayer in the inscription, "*Nād-i ᶜAlī*" (engraved on the horizontal bar of the rete) which is held in high reverence in Shia sect, indicates that he was a Shia. An elite Shia family of ᶜAlī Razā Khān (d.1865) and his son Nawāb Nawaizh ᶜAlī Khān participated in the development of Lahore and patronized scholars and artisans.[29] It is likely that Mubārak ᶜAlī Khān may have belonged to this family.

Pīr Baksh is mentioned by another famous historian of Lahore, Rai Bahadur Kanhaya Lal (c. 1829–1888) in his book, *Tarikh-e-Lahore* (تاریخ لاہور, *The History of*

28 Griffin 1873: 493–494.

29 Lal 1884: 74.

Lahore). He writes that Pīr Bakhsh was a dignified person, well known in the Sikh court, a prominent expert in Persian calligraphy and was a metal engraver.[30]

> اس شهر کا فارسی و عربی خط ولاءیتوں میں مشهہور تھا
> سکھی وقت میں فارسی خوش نویس میاں پیر بخش کوفتہ گر تھا
> اوراس کی عزت تمام امرائے دربار بلکہ خود راجہ کرتا تھا
>
> Arabic and Persian Calligraphy of this city [Lahore] was well known in various countries. In good peaceful times, there was a Persian calligrapher Miān Pīr Bakhsh, who was a metalworker as well. He was respected by the courtiers and by the Raja himself.

A famous Pakistani artist and writer on arts, Abdul Rahman Chughtai (1897–1975) states that during the Sikh reign the families of artists including Mian Imām Bakhsh and his father Pīr Bakhsh lived in the Khiradi Mohalla (خرادی محلہ *Khirādī Mohallah*) of Lahore.[31] If Pīr Bakhsh produced any other astrolabes, these have not come down to us.

3 CONCLUSION

THE PRESENT ASTROLABE was designed by Lālah Bulhomal, who was a Hindu and a member of the Khatri caste. Though resident in Lahore, he was closely associated with the princely state of Kapurthala which was ruled by the Sikhs of Ahlūwāliya family. Bulhomal dedicated a large North-South astrolabe, dated 1 January 1851, to Rājā Sāḥib Nihāl Singh Bahādur Ahlūwāliya, the ruler of Kapurthala State.[32] He dedicated a standard Indo-Persian astrolabe, dated 1849, to Sir Henry Elliot K.C.B., Chief Secretary to his Lordship the Governor-General.[33] This Henry Elliott is famous for the multivolume *History of India as told by its Historians*. Ghulām Qādir Kapūrthalī, in his astrolabe of 1861–62 states that he was a pupil (*shāgird*) of Bulhomal, the astronomer (*munajjim*) of Lahore.[34]

Mention may be made here of Joshī Dharm Chand (fl. 1854–73); he did not directly participate in the preparation of this astrolabe but belonged to the same cultural milieu. He was a Hindu of the Brahmin caste, educated in Persian, and trained in making traditional astronomical instruments.[35] On two of his instruments, the labels are in Sanskrit, but the signature is in Persian: *taṣnīf Joshī Dharm Chand sambat 1911* (Invention of Joshi Dharm Chand, Vikrama Saṃvat 1911 = 1854–55).[36] He was also the first to produce English perpetual calendars with

30 Lal 1884: 51.
31 Majīd 1987: 206.
32 Sarma 2021: B025.
33 Sarma 2021: B021.
34 Sarma 2021: B027.
35 Sarma 2021: 3945–3946.
36 Sarma 2021: U006 and U007.

equivalent Sanskrit solar months and days. There exist six specimens, four are engraved with Persian letters and numerals and designated as *ikhtirāᶜ naw* (new invention)[37] and two in English letters and numerals.[38]

The astrolabe was fabricated by Pīr Bakhsh of Lahore, who was a Muslim. It was made at the initiative of Mawlwī Ghulām Muḥammad, a Muslim of the Sunnī sect. It was made for Mubārak ᶜAlī Khān who appears to be a member of an influential Shia Muslim family. Thus people of diverse faiths and sects participated in the creation of this astrolabe. Moreover, it is dated in three eras belonging to three cultural traditions: Vikrama Saṃvat 1897, Hijrī 1257 and Anno Domini 1841.

Thus this astrolabe is a unique testimony to an intercultural collaboration.

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37 Sarma 2021: X015-X018.

38 Sarma 2021: X019 and X020.

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