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Indian Astronomical Instruments in German Collections

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INDIAN ASTRONOMICAL INSTRUMENTS IN GERMAN COLLECTIONS

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1 Introduction

While working on Sawai Jai Singh's masonry instruments and their antecedents several years ago,[1] I asked myself the question about the kind of instruments that were used by Indian astronomers before Jai Singh's time. To be sure, Sanskrit astronomical *Siddhāntas* —starting from Brahmagupta's *Brāhmasphuṭasiddhānta*, composed in AD 628—usually devote a chapter each for the description of various types of instruments for measuring time, for taking the altitude and azimuth of heavenly bodies, or for visually demonstrating the apparent motion of the heavens.[2] Contact with Islamic astronomy led, from about the fourteenth century onwards, to the composition of texts exclusively devoted to instruments. Astronomers also began to emphasise that astronomical studies would remain incomplete without proper observational instruments.[3]

Abbreviations used:
IJHS = *Indian Journal of History of Science,* New Delhi.
SHMS= *Studies in History of Medicine and Science*, New Delhi.

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[1] Cf. Sreeramula Rajeswara Sarma, *Yantraprakāra of Sawai Jai Singh*, edited and translated, Supplement to SHMS, 10-11 (1986-87).

[2] This literature has been ably surveyed by Yukio Ohashi in "History of Astronomical Instruments of Delhi Sultanate and Mughal India," SHMS, 10-11 (1986-87) 165-182; idem, "Astronomical Instruments of Bhāskara II and After" in: B. V. Subbarayappa and S. R. N. Murthy (ed), *Scientific Heritage of India*, Bangalore 1988, pp. 19-23; idem, "Astronomical Instruments in Classical Siddhāntas," IJHS, 29.2 (1994) 155-313; "Early History of the Astrolabe in India," IJHS, 32.3 (1997) 199-295; idem, "The Cylindrical Sundial in India," IJHS, 33 (1998) S-147-205. On Brahmagupta, see Sarma "Astronomical Instruments in Brahmagupta's Brāhmasphuṭasiddhānta," *Indian Historical Review,* 13 (1986-87) 63-74.

[3] Thus in 1370 Mahendra Sūri declares in his *Yantrarāja* (ed. Kṛṣṇaśaṃkara Keśavarāma Raikva, Bombay 1936) 1.4:

> *yathā bhaṭaḥ prauḍharaṇotkaṭo 'pi*
> *śastrair vimuktaḥ paribhūtim eti /*
> *tadvan mahājyotiṣanistuṣo 'pi*
> *yantreṇa hīno gaṇakas tathaiva //*

The question then arises whether any of these instruments described in the Sanskrit texts were ever constructed and used in observation. Are there any specimens extant where one can see how the textual prescriptions were executed in practice? Not finding any documentation on instruments used before Jai Singh, I decided to explore the museums and other collections and to identify pre-modern astronomical instruments. Such a survey, I hoped, would be useful because the actual specimens might help in understanding the texts. Conversely, textual knowledge would help in identifying an instrument and in dating its original design.[4]

During the past years, I visited scores of museums in several countries and located some 430 Indian instruments in museums and private collections in India, Europe and North America. I am currently preparing a descriptive catalogue of these instruments.[5] The catalogue will contain historical surveys of each instrument-type, its use and geographical spread, and full technical description of each one of the 430 extant specimens with art-historical notes. I shall also examine the relation between the theoretical prescriptions on instrument making in Sanskrit treatises and their actual execution in practice, and the interplay between Sanskrit and Islamic traditions of instrumentation.

"Just as a soldier, though hardened in fierce battles, is defeated when deprived of his weapons, even so the astronomer, though possessing a deep knowledge of the astral science, is disgraced when he is without instruments."

Writing about half a century later, in 1428, Rāmacandra Vājapeyin echoes the same idea in his *Yantraprakāśa* (MS no. 975/1886-92, Bhandarkar Oriental Research Institute, Pune) 1.10:

tanur netrair nyūnā nṛpatirahitā rājanagarī
sarasyo niṣpadmā yuvatir api kāntena rahitā /
niśā niḥśītāṃśuḥ sarid api yathā cakrarahitā
tathā jyotirvidyā bhavati viphalā yantrarahitā //

"Like body without eyes, royal capital minus the king, lakes devoid of lotus flowers, young woman without a lover, night without the moon, river bereft of *Cakravāka* birds, astronomical learning without instruments becomes fruitless."

[4] For a prospectus of this survey, see Sarma "Indian Astronomical and Time-Measuring Instruments: A Catalogue in Preparation," IJHS, 29.4 (1994) 507-528.

[5] Two catalogues of individual collections have appeared: Sarma, *Astronomical Instruments in the Salar Jung Museum,* Salar Jung Museum, Hyderabad 1996; idem, *Astronomical Instruments in the Rampur Raza Library,* Rampur Raza Library, Rampur 2003.

1.0 Survey of German Collections

This paper deals with the Indian astronomical instruments preserved in German collections. I surveyed these instruments in the winter of 1995-96, when I was awarded a research grant by the German Academic Exchange Service to work at the renowned Institut für die Geschichte der Naturwissenschaften of the Johann Wolfgang Goethe-Universität, Frankfurt. The Institute was founded and led for many years by Professor Willy Hartner, who wrote a classic study of the astrolabe, [6] an instrument that was held in high esteem throughout the medieval world, from the India of Fīrūz Shāh Tughluq to the England of Geoffrey Chaucer. During my visit, the Institute was headed by Professor David A. King who is an eminent authority on medieval astronomical instruments, both Islamic and European. More important, he was compiling a descriptive catalogue of all medieval Islamic and European astronomical instruments— precisely the kind of work I was planning to do for Indian instruments and for I which sought his guidance.[7]

I was also privileged to use the facilities of the other renowned Frankfurt institution, viz. Institut für die Geschichte der Arabisch-Islamischen Wissenschaften, through the kindness of its founder and director, Professor Fuat Sezgin. Besides producing the monumental *Geschichte des arabischen Schrifttums,* Professor Sezgin was engaged at that time in creating a museum of Arab-Islamic science and technology with original instruments, replicas and reconstructions. This unique museum is now ready, with a catalogue consisting of five fabulous volumes.[8]

Compared to the intellectual support I received from Professors King and Sezgin and from the excellent libraries of their institutions, the actual specimens of Indian instruments in the German collections are not many. However, some of these instruments were the subject of valuable studies by German scholars. In subsequent

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[6] Willy Hartner, "The Principles and Use of the Astrolabe" in: idem, *Oriens-Occidens*, [Vol. I], Hildesheim 1985, pp. 287-311; repr. Fuat Sezgin et al (ed), *Astronomical Instruments and Observatories in the Islamic World: Texts and Studies,* vol. X, Frankfurt 1998, pp. 338-375.

[7] See http://www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html for an outline of the project and a preliminary table of contents. For his publications on astronomical instruments— too numerous to be listed here— visit http://web.uni-frankfurt.de/fb13/ign/ign2/people/kinge.html .

[8] Fuat Sezgin, *Wissenschaft und Technik im Islam: Katalog der Instrumentensammlung des Instituts für Geschichte der Arabisch-Islamischen Wissenschaften,* 5 Bde, Institut für Geschichte der Arabisch-Islamischen Wissenschaften an der Johann Wolfgang Goethe-Universität Frankfurt am Main, Frankfurt 2003.

visits to Germany, I had the opportunity to study some more instruments in private collections. Today, the number of Indian instruments in German collections stands at the modest level of 12, but some of these are quite unique. Full technical descriptions of these instruments will appear elsewhere. Here I shall concentrate on the social and cultural context in which these instruments were produced.

1.1 **Water Clock.** Before describing these instruments, I must first mention five instruments which were once in Germany but are not traceable any more. Hermann von Schlagintweit-Sakünlünski, who undertook a scientific expedition to northern India between 1855 and 1857, brought back many artefacts from India. In 1871 he sent a communication to the Royal Bavarian Academy of Sciences at Munich on the water clocks he had acquired in India.[9] The water clock described by the baron is of the sinking bowl type, called *Ghaṭī*-or *Ghaṭikā-yantra* in Sanskrit. It consists of a hemispherical copper bowl with a small perforation at the bottom. When the bowl is placed on the surface of the water in a larger vessel, water enters the bowl through the hole, fills the bowl gradually and causes it to sink to the bottom of the basin. The hole is so made that the bowl fills up and sinks in a specific interval of time, usually 24 minutes, called *ghaṭī* or *ghaṭikā* in Sanskrit. This period is the sixtieth part of a nychthemeron (*ahorātra*), and was the standard unit of time measurement in India.[10]

The instrument was described by Āryabhaṭa towards the close of the fifth century and by several other astronomers later on. From the fifth century onwards, institutions for time keeping are attested at Buddhist monasteries, royal palaces, town squares etc., where time was measured regularly with this water clock and the passage of each *ghaṭī* was announced by drum beats or strokes on a gong. It was used throughout South Asia and South-East Asia until the beginning of the twentieth century.

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[9] Hermann von Schlagintweit-Sakünlünski, "Eine Wasseruhr und eine metallene Klangscheibe alter indischer Construction," *Sitzungsberichte der mathematisch-physikalischen Classe der k. b. Akademie der Wissenschaften zu München,* 1 (1887) 128-139.

[10] See Sarma "The Bowl that Sinks and Tells Time," *India Magazine, of her People and Culture,* 14.9 (September 1994), pp. 31-36; idem, "Setting Up the Water Clock for Telling the Time of the Wedding," in: Charles Burnett et al (ed), *Studies in the History of the Exact Sciences in Honour of David Pingree*, Brill, Leiden 2004, pp. 302-330.

In his communication to the Munich Academy, Schlagintweit-Sakünlünski reported that he brought back two bowls from Panipat and Varanasi and one metal gong. Both the bowls, he adds, were made to measure three *ghaṭikās* each (i.e. 72 minutes). It is, of course, theoretically possible to prepare a bowl that sinks in any given period of time. A bowl that sinks in 3 *ghaṭikās* is in fact mentioned in the middle of the fifth century by Buddhagoṣa in his commentary *Papaṃcasūdanī* on the *Majjhimanikāya*.[11] Now almost all the specimens of this instrument that I located in various museums are smaller bowls made to measure 24 minutes. Therefore, I was keen to see Baron Schlagintweit-Sakünlünski's larger bowls. His collection of Indian artefacts were housed originally in his family estate Jägersburg in Saarland. Some of these items are now held by different museums;[12] but there is no trace of the two water clocks, nor of the gong.

1.02 Column Dial

Let us now turn our attention to a little more complex instrument which measures time on the basis of the shadow thrown by the sun. Shadow instruments were in fact older than water clocks. From times immemorial, man estimated the passage of time by the change in the length of the shadow: at first the shadow of man, later the shadow of any vertically placed stick or gnomon. Indeed the Sanskrit word for gnomon shadow is *narabhā,* literally man's shadow. In the course of time, many varieties of sundials were developed, with various kinds of gnomons and dials.

In one of these varieties, the gnomon is inserted horizontally into a hole at the top of a circular or prismatic column of wood and throws its shadow on the length of the column. Below the hole is a scale to measure the shadow in terms of *ghaṭīs* counted from the sunrise to midday, or from midday up to the sunset. However, since the sun's movement across the sky changes according to seasons, different scales are needed for different seasons. Accordingly, separate scales for each solar month, or pairs of solar months, are marked on the different facets of the prismatic column. Such column dials

[11] Professor Oskar von Hinüber deserves credit for drawing attention to this passage in his highly valuable paper "Probleme der Technikgeschichte im alten Indien," *Saeculum,* 29.3 (1978) 215-230; see also idem, "Some Problems of the History of Technology in Ancient India," *Max Mueller Bhavan Yearbook 1978,* New Delhi 1978, pp. 36-51.

[12] See A. Armitage, "The Schlagintweit Collection," IJHS*,* 24.1 (1989) 67- 83.

existed in Europe under the name *horologium viatorum,* and also in the Islamic World, whence they may have reached India.[13]

In the nineteenth century, a type of wooden column dial became popular in the Nepal-Darjeeling region. Here the numbers on the scales and the names of the months for which each scale is meant are carved in high relief in the wood.[14] I have seen about a dozen specimens in Europe, but not a single one in India.[15]

According to an anonymous report in the *Deutsche Uhrmacher-Zeitung* for 1 October 1898, a specimen of this wooden column dial was displayed in "Die Uhren-ausstellung in der Urania," in Berlin.[16] But this specimen is no more extant in any German collection.

1.03 Kamāl

Also lost is an ingenious navigational instrument called *Kamāl* which was used for the latitude measurements in the Indian Ocean area. The Museum für Völkerkunde, Hamburg, acquired a specimen from Calcutta in 1882. In the same year, it was described by A. Schück in an article entitled "Ein altes indisches und arabisches Instrument zum Bestimmen der Polhöhe gewisser Orte." [17] This instrument consisted of a 4 mm thick oblong wooden board measuring 6.65 x 4.8 cm. Running through a hole at the centre of the board was a rope on which 16 knots were made. These knots served to find the latitudes of 16 localities on the coast of the Bay of Bengal. This unique instrument was lost, according to the Museum, during the World Wars.

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[13] Ohashi, "The Cylindrical Sundial in India," IJHS, 33 (1998) S-147-205.

[14] Winter, H. J. J. "A Shepherd's Time-Stick, Nāgarī inscribed," *PHYSIS: Rivista Internazionale di Storia dello Scienze*, 4 (1964) 377-384.

[15] Sarma, "Indian Astronomical and Time-Measuring Instruments: A Catalogue in Preparation," IJHS, 29.4 (1994) 507-28, esp. 516, Fig. 3.

[16] Anon, "Die Uhren-ausstellung in der Urania," *Deutsche Uhrmacher-Zeitung*, 22.19 (1 October 1898) 472-473.

[17] A. Schück "Ein altes indisches und arabisches Instrument zum Bestimmen der Polhöhe gewisser Orte," *Das Ausland* (Stuttgart), 65 (1892) 814; repr. Fuat Sezgin (ed), *Islamic Geography*, vol. 18, pp. 183. See also James Princeps, "Note on the Nautical Instruments of the Arabs," *Journal of the Asiatic Society Bengal*, 5 (December 1836), 784-795; repr. Fuat Sezgin (ed), *Islamic Geography*, vol. 15, pp. 139-151; Fuat Sezgin, *Wissenschaft und Technik im Islam,* III, Frankfurt 2003, pp. 42-45.

2.1 Armillary Sphere: Linden Museum, Stuttgart.

I shall now take up the instruments that are actually extant in German collections. The Linden Museum in Stuttgart has an armillary sphere, which is said to be from the collection of the Maharaja of Gwalior. The armillary sphere was described by Ptolemy in his *Almagest.* It was also discussed in almost all the Sanskrit astronomical *Siddhāntas* under the name *Gola-yantra.* Consisting of several rings to represent the various great and small circles in the heavens, this teaching device is very useful in demonstrating the planetary orbits and the position of important stars in the skies.

In the specimen at Stuttgart, there are two sets of rings, one inside the other, around a wooden staff which is 80.5 cm long. The outer ring has a diameter of 57 cm, the inner ring of 50.6 cm. Actually each set of rings constitutes an armillary sphere by itself. Some of the rings in shining brass appear to be quite recent, others in rusty iron are old. The brass rings are graduated in single degrees and in groups of 5 and 10. In the outer set can be seen one ring representing the celestial equator, another the ecliptic. Two other rings are attached perpendicularly to these two. There are also several smaller rings parallel to the equator and the ecliptic.

There is no signature of the maker, nor the date of manufacture. But it is likely that it was made in the nineteenth century. Even so it is a valuable specimen, because it is one of the few specimens which are still extant.[18]

2.2 Astrolabe by the Sons of Īsā, AH 1018 / AD 1609, Kestner Museum, Hannover.

The largest group of the surviving Indian instruments is that of the two Islamic instruments, the astrolabe and the celestial globe and their derivatives. Of the 430 Indian instruments which I catalogued, the astrolabes number about 190 and the celestial globes 80. This is not surprising because these are highly complex instruments, the production of which requires a sound knowledge of applied astronomy and trigonometry and a great skill in metal craft. Because of the mathematical complexity and aesthetic appeal, they are also valued collector's items.

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[18] Only three other specimens are known which are now at the Royal Scottish Museum, Edinburgh; Jai Singh's Observatory, Jaipur; and the Palace Museum, Kota. On the Kota armillary sphere, see Virendra Nath Sharma, "Astronomical Instruments at Kota," IJHS*,* 35.3 (2000) 233-244.

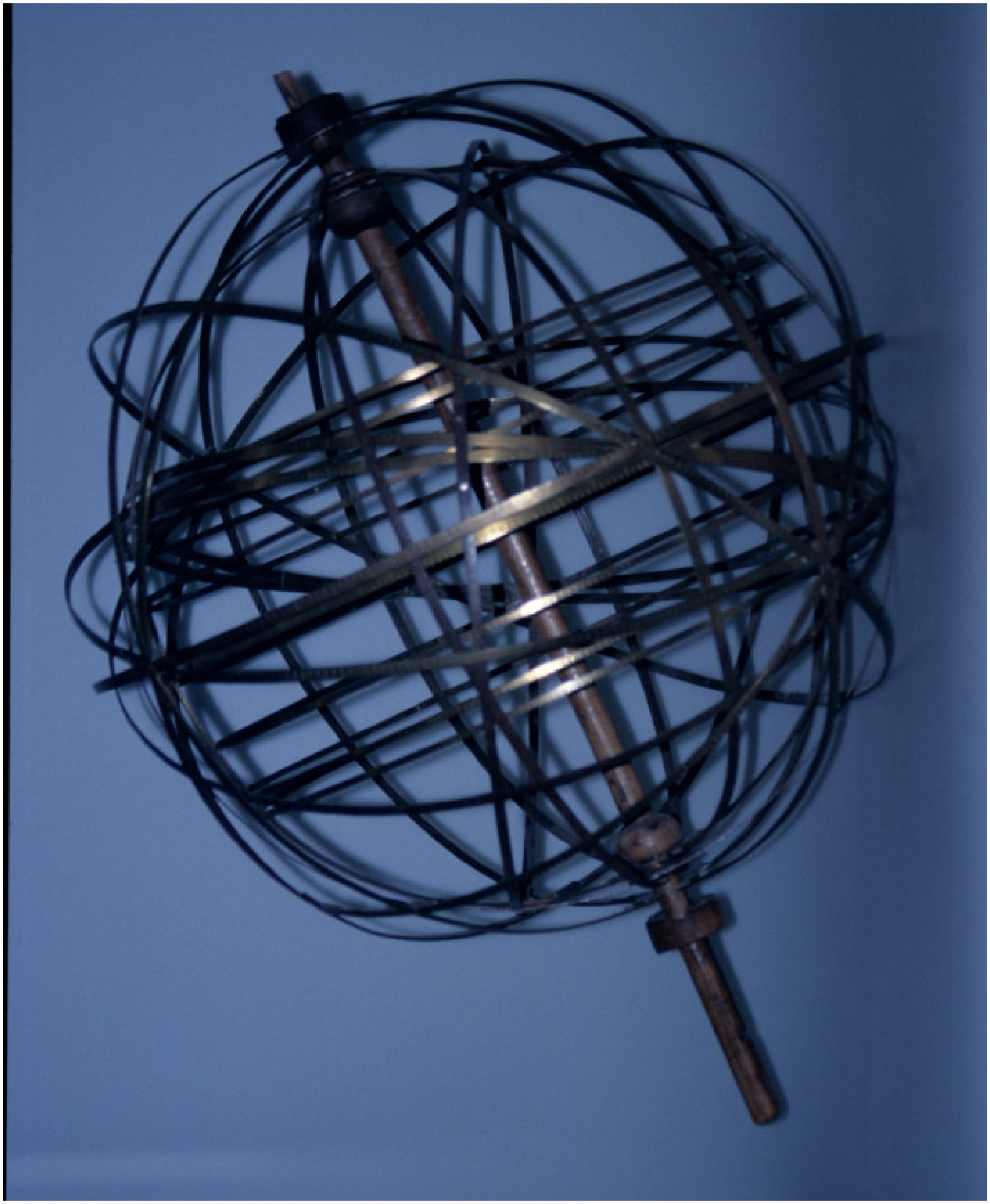

Fig. 1: Sanskrit Armillary Sphere, Linden Museum, Stuttgart.

The astrolabe was introduced into India in the eleventh century by al-Bīrūnī who wrote extensively on this instrument, and who claims to have composed two works on the astrolabe in Sanskrit verse. The manufacture of the astrolabe appears to have begun in India under Fīrūz Shāh Tughluq.[19] He is said to have commissioned several astrolabes and also manuals in Persian and Sanskrit. None of these survive, save the manual in Sanskrit composed by Mahendra Sūri in 1370. Islamic instruments like the celestial globe and the sine quadrant may also have been introduced about the same time.

But the earliest extant specimens, both of the astrolabe and the celestial globe pertain to the Mughal period. One family distinguished itself in their production. My survey has brought to light nearly 125 astrolabes and celestial globes crafted by seven members of this family, belonging to four generations. Some of these instruments were commissioned by high Mughal nobility and carry their names. The founder of the family is Allāhdād who appears to have migrated from Samarqand and set up his workshop at Lahore under the patronage of the Mughal emperor Humāyūn.[20]

The Kestner Museum at Hannover holds a small brass astrolabe purported to have been produced in this Lahore family in AH 1018 (= AD 1609-10). Joseph Frank and Max Meyerhof devoted a full-length monograph to this astrolabe.[21] It is a small specimen with a diameter of 8.4 cm. The main body called mater has an upraised rim all around. Two concentric circular scales are engraved on this rim. The inner scale is graduated for single degrees, while the outer scale is divided groups of 5º . In the recess created by the rim are stacked 5 plates and an openwork plate, the last one constituting the star-map called *'ankabūt* in Arabic. On it are displayed the tropic of Capricorn, the equator and somewhat off the centre the ecliptic. The ecliptic circle is divided into the 12 signs of the zodiac and labelled accordingly. On both sides of the ecliptic are marked the positions of 21 prominent stars, represented by projecting tips.

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[19] Sarma "Sulṭān, Sūri and the Astrolabe," IJHS, 35.2 (2000)129-47.

[20] Sarma, "The Lahore Family of Astrolabists and their Ouvrage," SHMS, 13.2 (1994) 205-224.

[21] Joseph Frank & Max Meyerhof, *Ein Astrolab aus dem Indischen Mogulreiche,* (Heidelberger Akten der von-Potheim-Stiftung, 13: Arbeiten aus dem Institut für Geschichte der Naturwissenschaften), Carl Winter's Universitätsbuchhandlung, Heidelberg 1925; repr. Fuat Sezgin et al (ed), *Astronomical Instruments and Observatories in the Islamic World: Texts and Studies,* vol. IV, Frankfurt 1998, pp. 307-356.

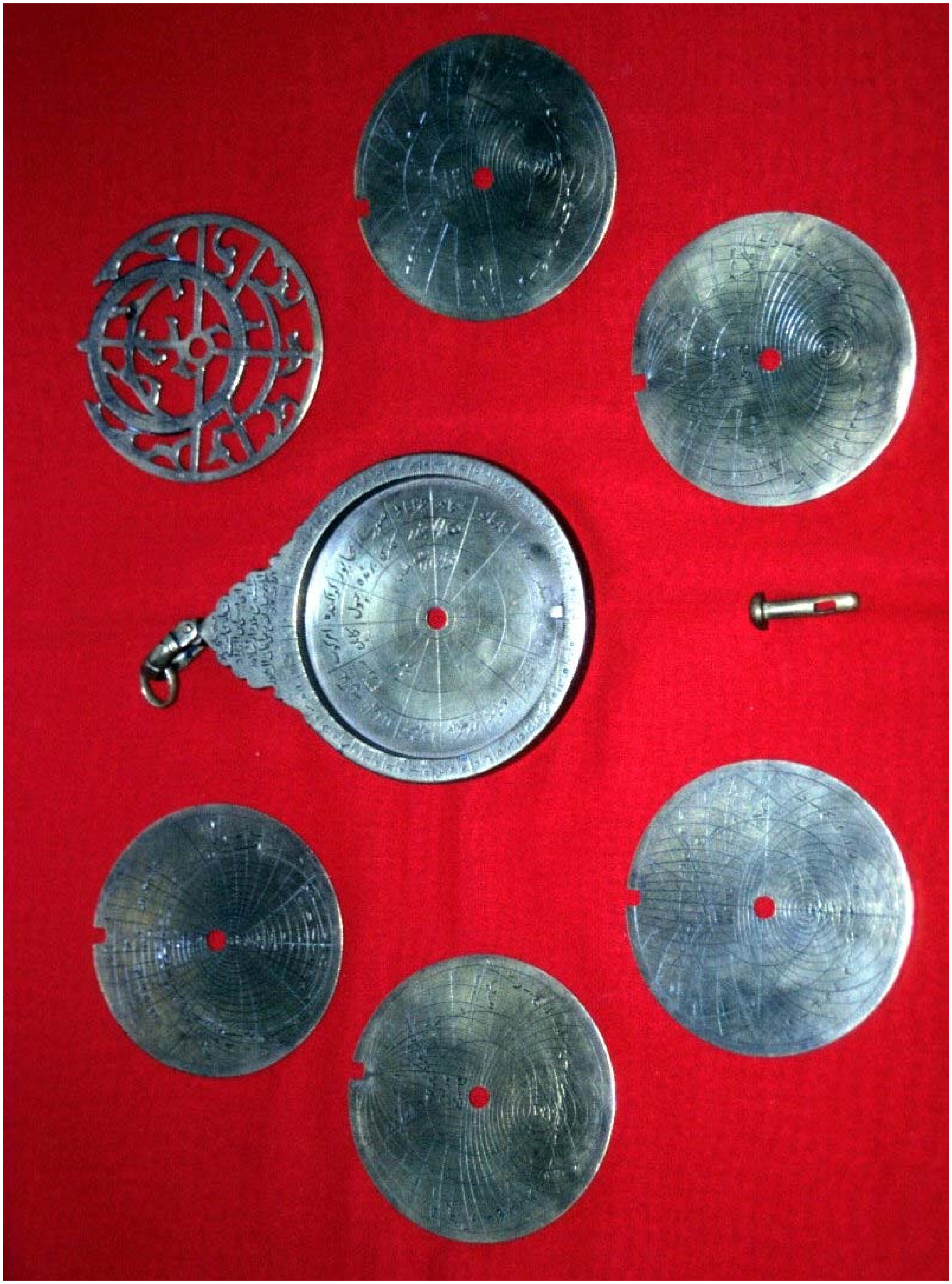

Fig. 2: Mughal Astrolabe, Components, Kestner Museum, Hannover.

The five plates are calibrated to serve different terrestrial latitudes between 18º and 39;37º. On the inner surface of the mater is engraved a geographical table or gazetteer, containing the names of some 65 towns, their longitudes and latitudes. However, many of the cells here remain blank and the gazetteer is engraved indiscriminately all over the astrolabe.

The back is divided into four quadrants, each of which is filled with trigonometric and astrological data. The upper left quadrant has a sine graph. The upper quadrant on the right is divided into 6 concentric arcs to represent the 12 zodiac signs. Superimposed on this grid is the sigmoid curve for the midday solar altitude at the latitude 32º, which is the latitude of Lahore. This curve is characteristic feature of the Lahore astrolabes.

In the lower left quadrant, two shadow squares are engraved one inside the other, with the tangent scale on the rim. The lower right quadrant displays, rather clumsily, the twelve signs of the zodiac and the corresponding lunar mansions.

Who made this astrolabe? On the suspension bracket, called *kursī,* there is an inscription stating that the astrolabe was made by the two sons of Īsā ibn Allāhdād (*ibnī ʻīsā ibn allāhdād*) in AH 1018 (= AD 1609) in Lahore. The names of the two sons are not mentioned. From the extant instruments, we know that Allāhdād's son Īsā had two sons named Qā'im Muḥammad and Muḥammad Muqīm. Qā'im's surviving astrolabes and celestial globes are dated between 1622 and 1637. Muqīm's extant astrolabes are dated between 1621 and 1659. If the two sons mentioned in the 1609 astrolabe are really Qā'im and Muqīm, it is strange that there are no instruments made by them from the period between 1609 and 1621.

There is also a vast difference in the quality of production between the Kestner astrolabe and the elegant and ostentatious productions of Qā'im and Muqīm which were sought after by high Mughal nobility. One possibility is that the Kestner astrolabe was their juvenile production and that they made great progress in their subsequent careers. It is also possible that the two sons mentioned on the astrolabe are not Qā'im and Muqīm but two other sons who may not have produced any other instrument after this (not very promising) astrolabe. A third, and more likely, possibility is that the inscription was added later on by somebody else. This possibility is supported by the fact that the gazetteer is not engraved by one person, but at least three.

2.4 Astrolabe by ‘Abd al-Qādir al-Muhibb, n.d., IGN, Frankfurt.

The Institut für Geschichte der Naturwissenschaften of the University of Frankfurt owns a large astrolabe with a diameter of 30.6 cm. This highly ornate astrolabe with an open work throne, an ornate rete with as many as 65 star pointers, and four plates, can be called the grandest of Indian astronomical instruments in German collections. On a cartouche in the throne is engraved the name of the maker: ‘Abd al-Qādir Muhibb. This instrument maker belonged to the seventeenth century. Other instruments by him and his son Luṭf Allāh ibn ‘Abd al-Qādir al-Muḥibb al-Asṭurlābī are known. His grand son Abū al-Khair Khair-ullah was the astronomical adviser to Sawai Jai Singh and wrote a commentary on the latter’s *Zīj-i Muḥammad Shāhī*. Another member of this family ‘Atā’ Allāh Rushdī (*fl.* 1634/35) translated Bhāskara’s *Bījagaṇita* into Persian.

Dr Petra Schmidl published an excellent study “Ein Astrolab aus dem 17. Jahrhundert: prachtvoll und verfälscht,”[22] where she showed how some unscrupulous persons tried to enhance the value of this astrolabe by inscribing the name of the great astronomer Naṣīr al-Dīn al-Tusī on the back of the cartouche.

2.4 Celestial Globe by Ḍiyā’ al-Dīn, AH 1070 / AD 1660, Museum für Indische Kunst, Berlin.

I mentioned that the majority of surviving Indian instruments is represented by the astrolabe and the celestial globe. The latter consists of a spherical globe with the ecliptic, the equator, tropics, polar circles, ecliptic latitude circles and other circles drawn upon it. A large number of star positions are also marked on the globe according to the coordinates given either by Ptolemy (for the year AD 138), or by Ulugh Beg (for AH 841 /AD 1437), or as calculated by others. Around specific clusters of stars are drawn constellation figures as conceived in Hellenistic mythology, or as modified later in the Islamic World. Ptolemy’s *Almagest* describes 48 such constellations constituted by

[22] Cf. Petra Schmidl, “Ein Astrolab aus dem 17. Jahrhundert: prachtvoll und verfälscht” in: *Ad Radices: Festband zum fünfzigjährigen Bestehen des Institut für Geschichte der Naturwissenschaften, Frankfurt am Main*, Stuttgart, 1994, pp. 282-305.

Fig. 3: Astrolabe by ‘Abd al-Qadir al-Muhibb, IGN, Frankfurt.
Photo Courtesy Dr Petra Schmidl.

some 1018 fixed stars and enumerates the ecliptic coordinates and magnitudes of these stars. Therefore, it was customary to draw 48 constellation figures and mark 1018 star positions, although there are globes with less number of stars.

At the two equatorial poles of the globe, holes are made for the axis to pass through, and this axis is pivoted inside a meridian ring, so that the globe rotates around the axis. The meridian ring is mounted perpendicularly upon a horizon ring which is supported by three or four legs. The axis can be so adjusted in the meridian ring that it is inclined to the plane of horizon by an angle equal to the terrestrial latitude of the place where the globe is to be used. Then the globe simulates the motion of the heavens above that place and the star positions on the globe correspond to those in the skies.

Qā'im Muḥammad of the Lahore family introduced an innovation in the production of the celestial globes by casting them as single hollow spheres through the lost wax process. Qā'im's son Ḍiyā' al-Dīn Muḥammad (*fl.* 1645-1680) excelled both his father, from whom he learnt the art of casting celestial globes in one piece, and his uncle Muqīm, who bequeathed to him virtuosity in designing astrolabes. Ḍiyā' al-Dīn's oeuvre consists of about 33 astrolabes and 16 celestial globes.[23]

The Museum für Indische Kunst in Berlin (which was incorporated into the Museum für Asiatische Kunst in December 2006) possesses a globe made by this Ḍiyā' al-Dīn in AH 1071 AH, which year corresponds to AD 1660. Here only the globe is extant; the axis, the horizon and meridian rings, and the stand are lost.

It is a small globe with a diameter of just 9.4 cm. On it globe are engraved the celestial equator and the ecliptic, both finely divided into degrees of arc and labelled. Besides these, several great and small circles are drawn. Against this grid of circles, the positions of about 1018 stars are marked with inlaid silver points. The points vary in size and attempt to depict different magnifications of the stars. Several of these stars are combined to form the 48 constellations. The anthropomorphic and zoomorphic forms of these constellations are neatly engraved. The globe was described in great detail by Harald von Klüber in 1935.[24]

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[23] Sarma, "From al-Kura to Bhagola: On the Dissemination of the Celestial Globe in India," SHMS, 13.1 (1994) 69-85; idem, "The Lahore Family of Astrolabists and their Ouvrage," SHMS, 13.2 (1994) 205-224.

[24] Harald von Klüber, "Über einen Arabischen Himmelsglobus aus Indien," *Baessler Archiv: Beiträge zur Völkerkunde*, 18 (1935) 1-21; repr. Fuat Sezgin et al (ed), *Astronomical Instruments and Observatories in*

Fig. 4: Celestial Globe by Ḍiyā’ al-Dīn, 1070/1660-62, Museum für Indische Kunst, Berlin.
Photo Courtesy Ms Regina Hickmann, Museum für Indische Kunst.

the Islamic World: Texts and Studies, vol. VIII, Frankfurt 1998, pp. 347-367. See also Emilie Savage-Smith, *Islamicate Celestial Globes: Their History, Construction and Use*, Washington, D.C., 1985, p. 230.

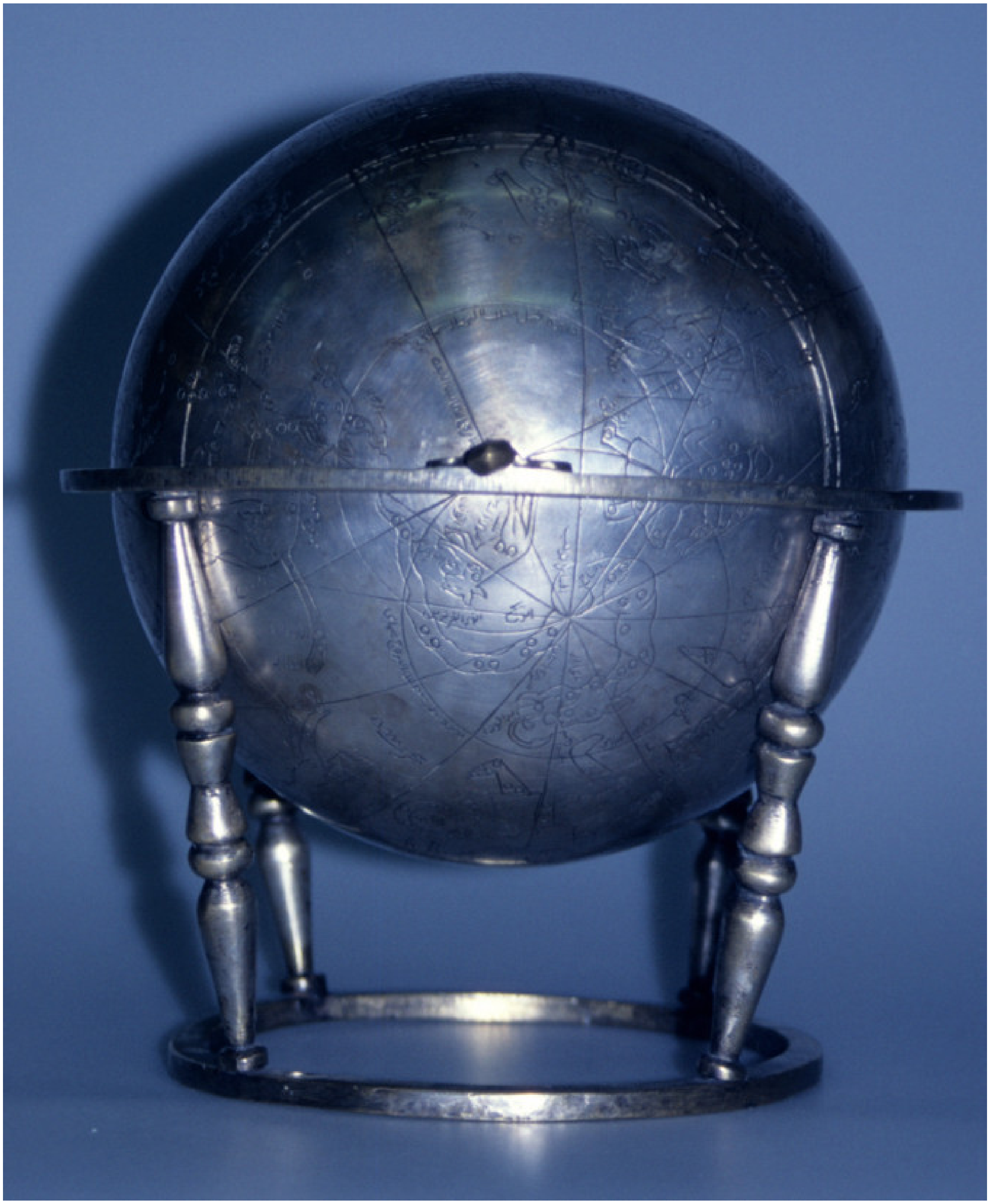

Fig. 5: Celestial Globe, Anon, n.d., Linden Museum, Stuttgart.

2.5. Celestial Globe, Anon, n.d., Linden Museum, Stuttgart.

A much larger globe of ca. 20.5 cm in diameter has been acquired by the Linden Museum of Stuttgart. This globe is set up on a stand of 15 cm height. Both the globe and the stand are made of brass, with a silver finish. The stand consists of a smaller circle below and the much larger horizon ring above, both the rings joined by four slanted legs. The horizon ring is graduated: the inner band into single degrees and the much wider outer band into groups of 6º, but these are not labelled. The axis of the globe is firmly affixed to the horizon ring, and no provision is made for the meridian ring. Consequently this globe can be used only at the equator and not at any other latitude north or south.

Like the Berlin globe, this was also cast in one piece. On it, the usual complement of great and small circles are engraved. One thousand and odd star positions are marked by dots enclosed by small circles, and the 48 constellation figures are drawn in outline. In several cases, the iconography of the constellation figures deviates from the standard practice. For example, the figure of Auriga (*mumsik al a'innah*) is represented by a seated man with two rabbits in his lap. The legends are engraved, not in flowing lines as in Mughal globes, but by irregular strokes. All these facts force us to conclude that this globe is not a product of the eighteenth century, as the Museum hoped, but of more recent times.

2.6 Sanskrit Astrolabe, Multiple plates, Anon, n.d., Private Collection.

I mentioned that Mahendra Sūri wrote the first Sanskrit manual on the astrolabe in 1370. He was so impressed by the versatile functions of the astrolabe that he called it *Yantrarāja*, "king of astronomical instruments." Since then the astrolabe is known by the name of *Yantrarāja* in Sanskrit.[25]

The response of the Hindus to this versatile instrument was very enthusiastic. They composed about fifteen manuals in Sanskrit on the astrolabe between the fourteenth and the eighteenth centuries. They also caused to be made a large number of astrolabes on which the legends were completely in Sanskrit. We call these Sanskrit astrolabes.

[25] Sarma, "Yantrarāja: The Astrolabe in Sanskrit," IJHS, 34 (1999) 145-158; see also idem, "Astronomical Instruments in Mughal Miniatures," *Studien zur Indologie und Iranistik,* 16-17 (1992) 235-276.

These Sanskrit astrolabes, however, differ from the Indo-Islamic astrolabes in the matter of workmanship. The Islamic astrolabes, whether in India or outside, were crafted by persons who were both astronomers as well as artisans. The same person made the technical design and then executed it from brass sheets. In the Hindu context, the design was drawn by a Brahmin astronomer (who was usually not a good draughtsman), and the actual manufacture was done by a brass worker who may not even be literate. Therefore, the calligraphy is generally of poor quality, often with orthographic errors. This dichotomy between the theoretician (*śāstrin*) and the artisan (*śilpin*) is more pronounced in the case of astronomical instrument making, because this craft never developed into a hereditary tradition as other craft forms like sculpture did. Therefore, not-withstanding the great enthusiasm shown by the Hindu *jyotiṣīs* towards the astrolabe, the specimens they got made were far from being precision instruments like the Islamic prototypes; at the most, they could be used as good teaching tools.

Such Sanskrit astrolabes must also have been produced since the fourteenth century at least, but the earliest extant ones are from the seventeenth century. Some nine or ten astrolabes made in this century came to light in course of my survey. The earliest surviving specimen was manufactured in 1607 at Ahmedabad for one Dāmodara.[26]

In a private collection in Germany, there is a Sanskrit astrolabe with multiple plates. Unfortunately it is neither signed nor dated. But in the geographical gazetteer, Jaipur is mentioned together with its latitude at 27º. Since this city was founded by Sawai Jai Singh around 1728, the present astrolabe must have been produced thereafter. It is a neatly crafted astrolabe with a diameter of 15.4 cm. The suspension bracket terminates in a trifoliate top; the surface of the bracket is covered on both sides with an identical floral design in bas relief. Such elegant brackets are rather rare in Sanskrit astrolabes.

In the rete or the star map (*bhapatra*) the circles of Capricorn, the equator and the ecliptic are almost fully represented (Fig. 7). These are held together by a broad

[26] This astrolabe is now in a private collection in Brussels. It was formerly in the Time Museum, Rockford, Illinois, USA, and was described by A. J. Turner, *Astrolabes, Astrolabe-related Instruments*, (The Time Museum, Catalogue of Collection, vol. I, part 1), Rockford, 1985, pp. 120-123, Figs. 100-104.

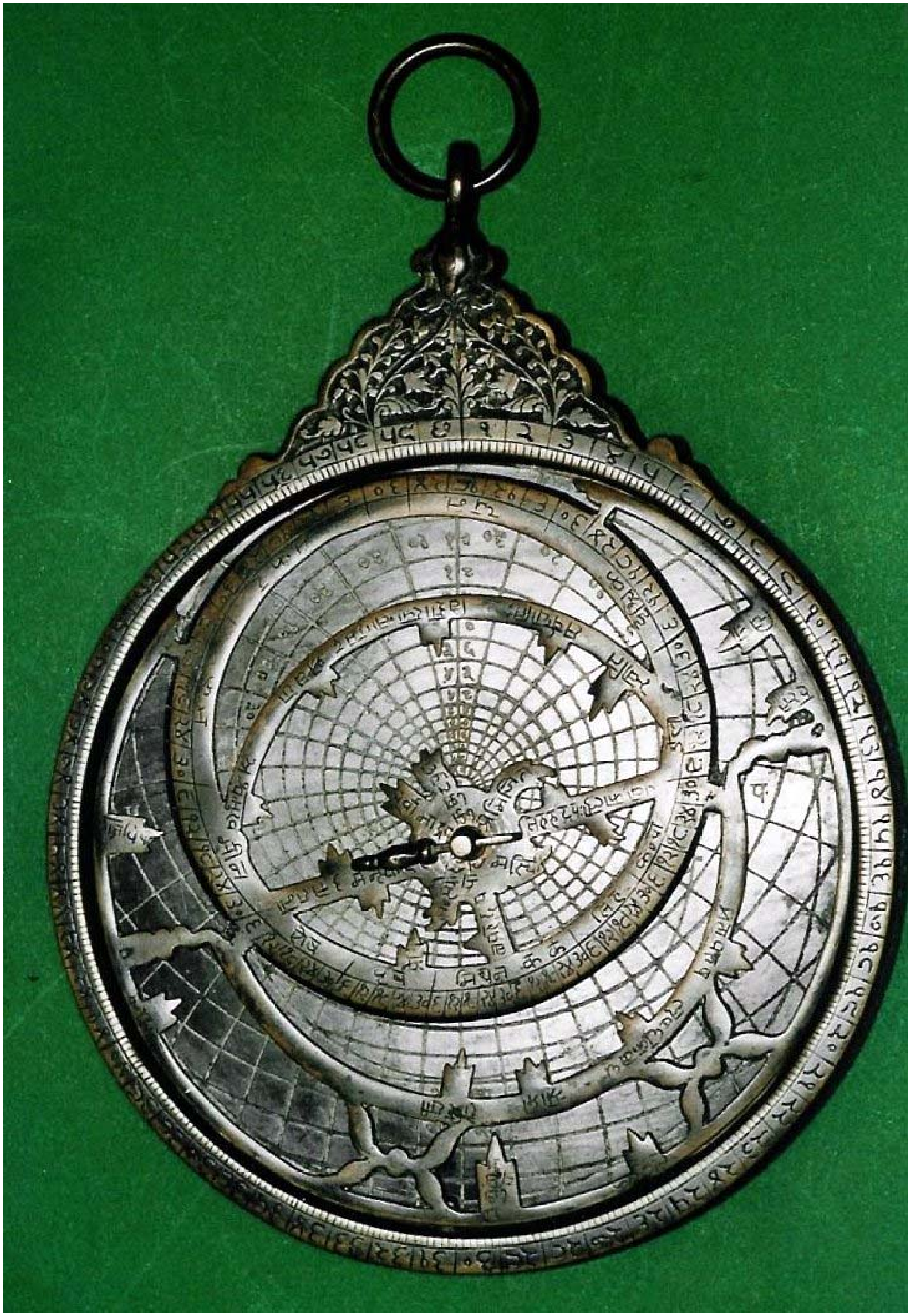

Fig. 6: Sanskrit Astrolabe, Anon, n.d., Front, Private Collection.
Photo Courtesy the Owner.

horizontal bar. The ecliptic is divided into the 12 signs of the zodiac and labelled; each sign is again subdivided into groups of 6º and labelled from 6 to 30. There are 26 dagger-shaped star pointers, 10 to the south of the ecliptic, i.e. outside the ecliptic, and 16 to the north. In three cases, the pointers are incorrectly positioned, viz. *Abhijit* (α Lyrae), *Kukkuṭapuccha* (α Cygni) and *Viśākhāmātṛmada*[27] (α Coronae Borealis).

Fig. 7: Sanskrit Astrolabe, Anon, n.d., Rete, Private Collection.
Photo Courtesy the Owner.

[27] Sic! it should read *Viśākhāmātṛmaṇḍala.*

There are five plates (*akṣapatra*), but these are calibrated only on one side, leaving the other side blank. This is very unusual. Normally the astrolabe plates are engraved on both the sides to save space. While the lines, curves and legends are engraved in flowing lines on the rest of the astrolabe, these are produced by acid on the plates. Furthermore, the numerals on these plates have quite modern forms as in print. Therefore, it appears that these plates are recent replacements, but made correctly and carefully. Two of these plates serve respectively the latitudes 25º (maximum daylight 13 hours) and 27º (13;42 h). The third plate has a double projection for two latitudes which I am unable to identify. The fourth is calibrated for the latitude of 66º, i.e., 90º minus the obliquity of the ecliptic; on this the ecliptic coordinates of the star pointers can be measured. The fifth plate has multiple horizons.

In the inner recess of the main body (see Fig. 8), a grid of 8 annular rings is engraved, but only four of these are filled with entries for the geographical gazetteer, providing the names and latitudes (but no longitudes) of 48 localities. These contain many names which occur here for the first time in astrolabe gazetteers, such as Jaisalmer, Bikaner, Jaipur, Mathurā, Badarīnātha and Haridvāra. This gazetteer is put together—rather indiscriminately—from diverse sources. Three cities are mentioned twice. Qandahar in modern Afghanistan is mentioned twice (no. 7 Kadāra 33º and no. 23 Kadhāra 33º). No. 14 Ḍholatāvāda 20;30º and no. 32 Devagirau 20;34º are identical, for the Yādava capital Devagiri was renamed Daulatabad after the Muslim conquest. Again, Golconda (modern Hyderabad) appears twice in two designations: no. 42 Molakuḍā (sic! for Golakoṇḍa) 18º and No. 16 Taila[ṃ]ge 18º. Trilinga or Tailanga is actually the designation for southern Deccan.

Sanskrit astrolabes do not carry on the back any astrological data as the Indo-Islamic astrolabes do. In the present astrolabe, the upper left quadrant on the back contains a sine-cosine graph. The upper right quadrant is divided into 6 concentric sections, to represent the 12 zodiac signs. Their names are engraved on the vertical and horizontal radii. There are shadow squares in the two lower quadrants, on the left for a gnomon of 12 digits and on the right for a gnomon of 7 digits.

The astrolabe lacks the alidade, pin and wedge.

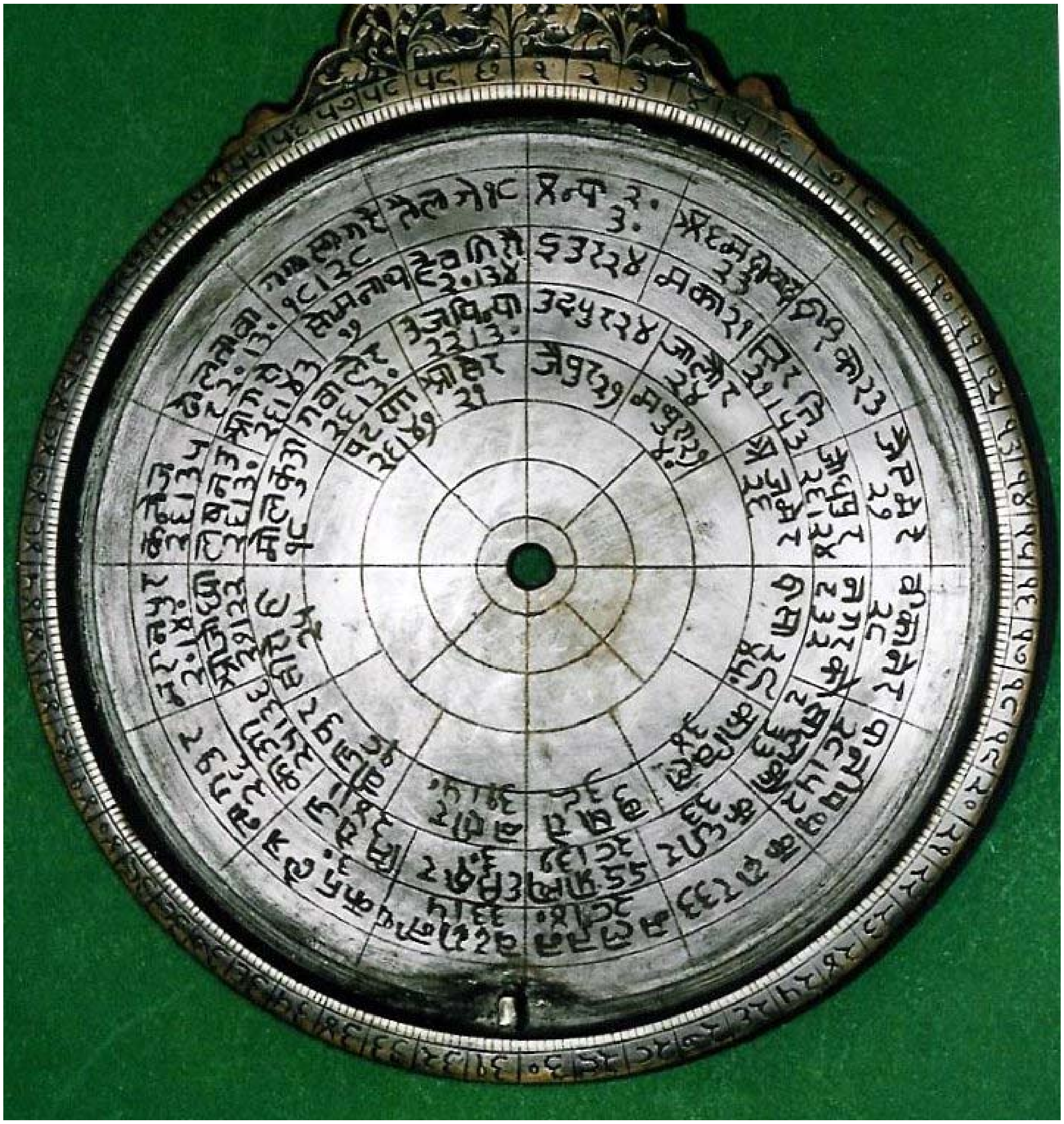

Fig. 8: Sanskrit Astrolabe, Anon, n.d., Geographical Gazetteer, Private Collection.
Photo Courtesy the Owner.

Single Plate Sanskrit Astrolabes

Although Jai Singh preferred large masonry instruments for astronomical observation, he had a great esteem for the astrolabe and composed a manual with the title *Yantrarājaracanā.* He also appears to have established a workshop for producing Sanskrit astrolabes. The main product were astrolabes with a single plate calibrated for 27° north, which is the latitude of Jaipur. Jai Singh seems to have realised, quite rightly, that the best way to popularise the astrolabe is to divest it of unnecessary peripherals and make it simpler. The simplest form naturally is an astrolabe with a single plate calibrated to one particular latitude. There survive a large number of such single plate Sanskrit astrolabes in almost all instrument collections. These were produced in Jaipur and other places in Rajasthan, Gujarat and the Punjab.

2.7 Sanskrit Astrolabe, anon, VS 1924 / AD 1867, Private Collection.

2.8 Sanskrit Astrolabe Raṇakuṃjalāla, n.d., Private Collection.

Three such single plate astrolabes are in German collections. Two of these are in a private collection. These were apparently produced by the same instrument maker in Jodhpur around 1867. The two are about the same size (diameter 21.3 cm, height 24.9 cm; diameter 20.7 cm, height 24.7 cm). The suspension bracket on the top of the main body is cut in the same style. Both are calibrated for latitude 26º on which Jodhpur is situated. On the suspension bracket of the first one is engraved *Saṃ 1924 rā / Jodhapuramadhye*, "In the Saṃvat year 1924, in the middle of Jodhpur." The year translates to AD 1867. The second astrolabe carries the inscription "*Om Om / Raṇakumjalāla*." This Raṇakuṃjaḷala is either the owner or more likely the maker.

The crudely made star maps (*bhapatra*) are almost similar with dagger-shaped star pointers engraved with the same set of 21 stars. The orthography in the names of the 12 zodiac signs and the 21 stars is rather poor.

The front (*akṣapatra)* is also similar with some minor differences. On both astrolabes, the rim has a double scale, the inner one being graduated for single degrees and the outer one into groups of 6º. But these groups of 6º are labelled differently in the two astrolabes. In the first one, the divisions are labelled separately for each quadrant, starting respectively from the east or west point and reaching to the south or north point;

in the second one the groups of 6º are numbered serially as 1, 2, 3 … 58, 59, 60 in the clockwise direction.

Fig. 9: Sanskrit Astrolabe, Single Plate, Private Collection.

Inside the rim are drawn the east-west and north-south lines, and the concentric circles for the tropic of Capricorn, the equator and the tropic of Cancer. Also engraved are equal altitude curves for each 3º, azimuth lines above and below the horizon for each 6º and unequal hour lines (these are dotted in the first one, plain in the second) counted as 1, 2, 3 … 10, 11, 12 from the western horizon. Therefore with these astrolabes, time can be measured only in Islamic fashion, in hours counted from the sunset, and not in *ghaṭīs* from the sunrise which was the general Hindu practice.

Fig. 10: Sanskrit Astrolabe, Single Plate, Private Collection.

On the back, in both the astrolabes, the upper right quadrant has a sine-cosine graph. In the case of the upper left quadrant, there is a difference. In the first astrolabe, five equi-distant concentric arcs divide the top left quadrant into 6 segments, on which are drawn 6 equal hour graphs. In the second astrolabe, there is a table of 12 columns and two rows with some syllables engraved in each cells. I am unable to say what this table denotes.

The lower half in both the astrolabes is occupied by a double shadow square. In the second astrolabe, the shadow square for a gnomon of 12 digits (*aṅgula*) is on the left and that for a gnomon of 7 digits on the right. These are labelled as such. In the first astrolabe, however, both the squares are drawn for a gnomon of 7 units. There are no labels.

In sum, both the astrolabes are nearly identical, but rather carelessly made. The divisions on the scales are not uniform. In the second astrolabe, several arcs were incorrectly drawn and then an attempt was made (unsuccessfully) to erase them. The orthography is generally poor in both of them. Both have sighting tubes attached to the alidades.

2.9 Sanskrit Astrolabe, Single Plate, Anon, n.d., Kunstgewerbesammlung der Stadt Bielefeld.

In contrast to these two astrolabes, the astrolabe preserved in the Kunstgewerbesammlung in Bielefeld is somewhat more neatly made.[28] It is also a large piece with a diameter of 30.3 cm. The suspension bracket is elegantly shaped with a pair of birds. The astrolabe plate is calibrated for the latitude of 24º.

The rim contains two concentric scales. The inner one is graduated for single degrees and the outer one is divided into groups of 6º. These groups are numbered serially from 1 to 60 in the clockwise direction. In the area enclosed by the scales are drawn equal altitude circles for each 6º and azimuth lines for each 6º above and below the horizon. The azimuth lines are not uniform. Strangely there are no hour lines, thus depriving the astrolabe of its time-measuring function!

[28] It is briefly described, without drawing attention to the unusual feature on the back, in Dirk Syndram, *Wissenschaftliche Instrumente und Sonnenuhren,* Kunstgewerbesammlung der Stadt Bielefeld, Stiftung Huelsmann, Callwey, München, 1989, pp. 64-65.

Fig. 11: Sanskrit Astrolabe, Single Plate, Anon, nd, Front,
Kunstgewerbesammlung der Stadt Bielefeld.

On the back, the rim is graduated, as in the front, in groups of 6º and in single degrees. The upper right quadrant is filled with a sine-cosine graph, and the lower right quadrant is occupied by a single shadow square drawn for a gnomon of 7 units.

Fig. 12: Sanskrit Astrolabe, Single Plate, Anon, nd, Back.
Kunstgewerbesammlung der Stadt Bielefeld.

The left half consisting of the upper and lower left quadrants is filled with the projection of a family of horizons from 12º to 66º, at an interval of 6º each. Usually such families of horizons are engraved on a plate of the astrolabe. This is the only astrolabe where this feature occurs on the back.

Interestingly, Joshī Dharam Chand made two identical quadrants where one side is filled by such a family of horizons. One of these is in the Linden Museum, Stuttgart.[29]

2.10 Quadrant-cum-Astrolabe Plate by Joshī Dharam Chand, VS 1911 / AD 1854, Signature in Persian, Legends in Sanskrit, Linden Museum, Stuttgart.

This instrument consists of a thick solid brass plate (width 16.5 cm, length 21.2 cm, thickness 0.3 cm). From one of the shorter sides of this oblong plate project two sighting vanes, which are made somewhat thicker than the rest of the plate. On the obverse side, at the top of the plate, there is the signature of the maker in Persian, which reads *taṣnīf joshī dharam chand sambat 1911,* "The invention [of] Joshi Dharam Chand, Saṃvat 1911." The year corresponds to AD 1854. The rest of the legends on this instrument are in Sanskrit and in Devanagari Characters.

A little above the middle of the plate is engraved a circle with a diameter of 16 cm. Inside the circle, there are two concentric circular scales; the inner one is graduated into single degrees and the outer one into groups of 6º and numbered, starting from the centre at the top and proceeding clockwise, as 01, 02, 03 …58, 59, 60. Inside the circle are drawn the south-north and west-east lines, circles of Cancer, the equator and Capricorn, as in the astrolabe plates, but without any labels.

On this frame are engraved the families of horizons for 4 sets of latitudes, as is done on the astrolabe plate for multiple horizons (*ṣafīḥa āfāqiya*). These are labelled where each horizon begins and where it ends. Unlike on the astrolabe plates, declination scales are not engraved here. The four sets of latitudes are as follows:

17	23	29	39	49	59
20	30	40	50	60	
22	32	42	52	62	
25	35	45	55	65	

[29] The second piece, also made in the same year, came for auction at the auction house of Skinners, Bolton, MA, USA, in 2002; cf. *Science & Technology featuring Mechanical Music,* Sale 2133, April 23, 2002, Auction Catalogue, Bolton, 2002, p. 36.

Fig. 13: Quadrant-cum-Astrolabe Plate by Joshī Dharam Chand, VS 1911 / AD 1854, Front.
Linden Museum, Stuttgart.

To the centre of the circle is pivoted an ornate rete, which rotates on the circle eccentrically. The rete is tightly fixed with an iron nail, which is probably a later addition. The rete consists just of the circle of the ecliptic, held up by two bars which are perpendicular to one another. The ecliptic is divided into the 12 zodiac signs and labelled, each sign is again subdivided into groups of 6º and numbered as 06, 12, 18, 24, 30. The edge is cut at right angles to the surface of the plate and marked with the degrees of arc. On the reverse side there is a finely executed sine quadrant.

This projection of multiple horizons is used for determining the times of sunrise and sunset at latitudes other than one's own, or to determine the latitude from the time of sunrise or sunset.[30] Dharam Chand singled out this feature from the Islamic astrolabes to create a new device which he called a *tasnīf,* an invention. Therefore it is reasonable to assume that the Bielefeld astrolabe may also have emanated from Dharam Chand or his group.

The title *Joshī* shows that Dharam Chand was a Brahmin. He was one of the few Brahmins who overcame the dichotomy between the *śāstrin* and the *śilpin* and tried their hand—quite literally—at instrument making. Five instruments made by Dharam Chand during the period 1954-75 are extant. These carry legends are in Persian, Sanskrit, or English. Brahmin by birth, educated in Persian, trained in metal craft and in making traditional astronomical instruments, he was also open new ideas from Europe. He seems to have been the first one to attempt at producing European perpetual calendars. There survive three specimens made by him; two are engraved in Persian and one in English. These are the earliest known prototypes of the brass perpetual calendars which are now mass-produced Muradabad.[31] Dharam Chand belonged to a group of traditional instrument makers who were active in Punjab around the middle of the nineteenth century, producing diverse types of pre-modern astronomical instruments with legends in Arabic-Persian or in Sanskrit.[32]

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[30] See Harold N. Saunders, *All the Astrolabes,* Oxford 1984, pp. 15-16.

[31] For a description of his perpetual calendars, see Sarma, *Astronomical Instruments in the Rampur Raza Library,* Rampur 2003, pp. 78-84.

[32] See Sarma, "Some Indo-Persian Astronomical Instruments of the early Nineteenth Century," *Khuda Bakhsh Library Journal*, No. 123 (April 2001) 1-16.

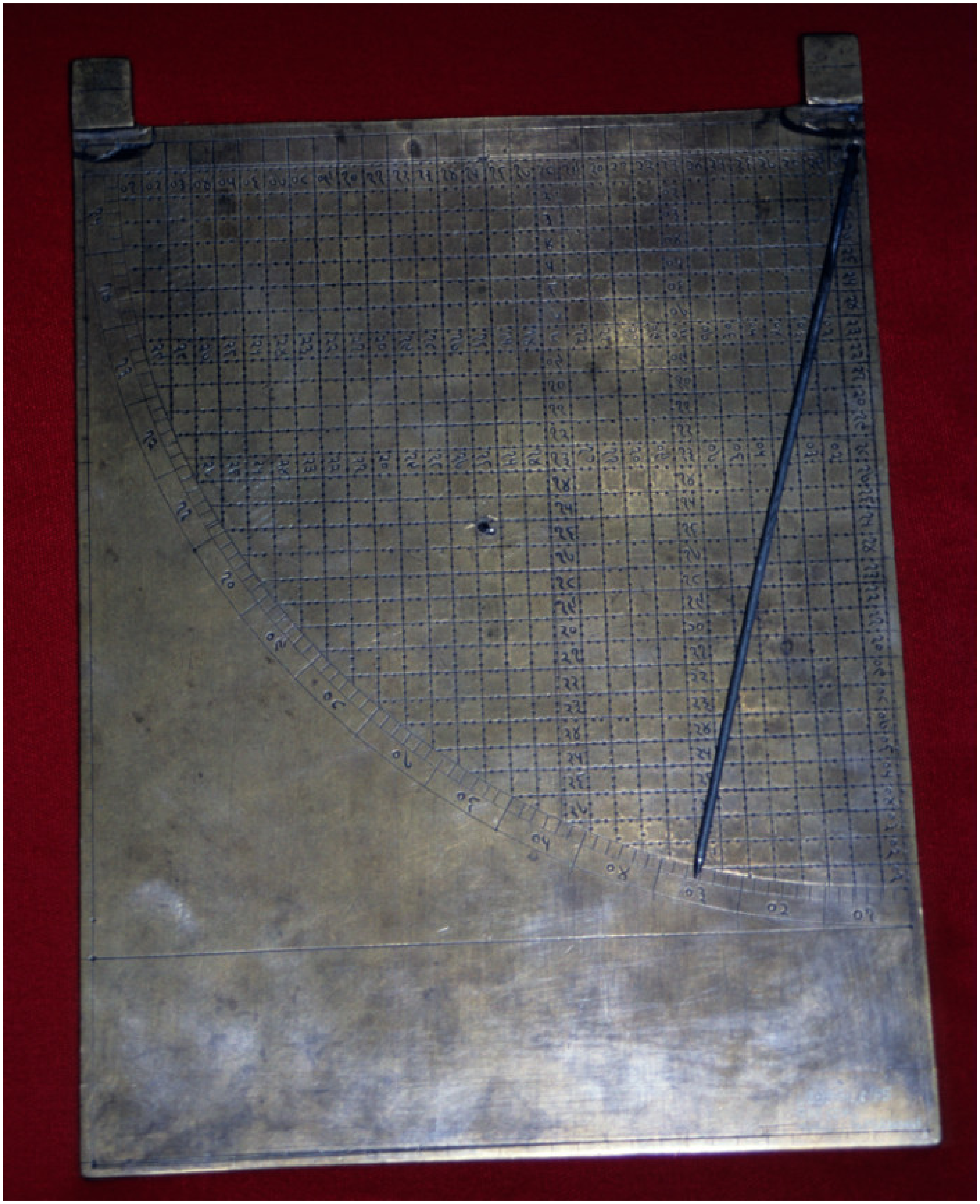

Fig. 14: Quadrant-cum-Astrolabe Plate by Joshī Dharam Chand, VS 1911 / AD 1854, Back.
Linden Museum, Stuttgart.

Punjabi Instruments

The nineteenth century Punjab saw also, for the first time, the production of instruments with legends in Punjabi language and Gurumukhi script. Three instruments are known, two of them in a private collection in Germany.

2. 11 Punjabi Double Quadrant or Cāpa-yantra.

The quadrant is one of the oldest astronomical instruments, known already to Ptolemy. It was employed in Europe, in the Islamic World and in India. In Sanskrit, it is called *turīya* or *turya-yantra.* It was used primarily for measuring the altitude of the heavenly bodies. In the first quarter of the seventh century, Brahmagupta describes the construction and use of the *turīya-yantra* in his *Brāhmasphuṭasiddhānta.* But he was of the opinion that a double quadrant is more convenient for astronomical observations and trigonometric calculations. He designates this double quadrant as *Dhanur-yantra,* "bow-shaped Instrument".[33] Other astronomers preferred another synonym *cāpa-yantra.*

Cāpa-yantras must have been produced and used by astronomers of India from Brahmagupta's time onwards. But the only extant specimen is in a private collection in Germany. It is made of copper with a diameter of 31 cm. Along the diameter is attached a sighting tube, made of brass, which has now become slightly bent. From the centre of the semicircle is suspended a plumb line, which passes through a hole in the centre and hangs on both sides of the quadrant, with a cone-shaped copper bead attached to each end. A 26.5 cm long handle with a fan-shaped top is attached to the double quadrant, at the central point of the arc. On the **obverse** side, on the fan-shaped top of the handle is engraved in Punjabi language and Gurumukhi script *hayahu cāp jīt rahai,* "May this bow [instrument] be victorious".

The semicircle is divided into two halves by a radius in the middle. On the left hand side quadrant, two semicircles are drawn along the vertical and horizontal radii. Through their intersection another radius is drawn, along which is engraved: *is rekhā se ucāī makān darakht kā mālūm hotā hai,* "with this line, the height of houses and trees becomes known".

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[33] Sarma , "Astronomical Instruments in Brahmagupta's Brāhmasphuṭasiddhānta," *Indian Historical Review,* 13 (1986-87) 63-74, esp. 66-67.

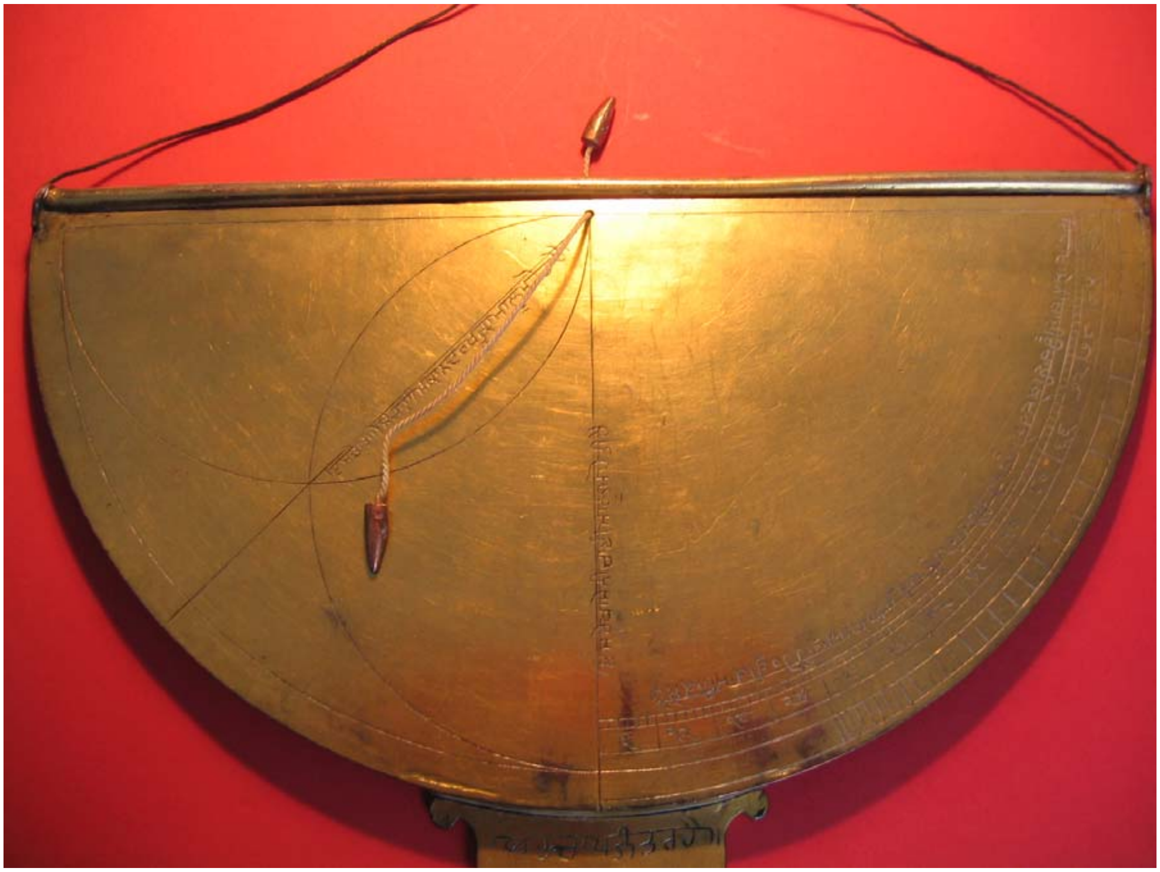

Fig. 15: Punjabi Double Quadrant, Anon, nd, Private Collection.

Along the vertical radius which divides the semicircle into two quadrants is engraved: *is rekhā se nīcāī mālūm hotā hai,* "with this line, the depth becomes known".

In the quadrant on the right hand side, there are three scales along the arc. The innermost scale is divided into single degrees. The middle scale is divided into groups of 6º, and is labelled as 6, 12, … 90, starting from the vertical radius and reaching up to the horizontal diameter. The outermost one is a co-tangent scale as is seen on the back of the astrolabes. Along these scales is engraved the fourth inscription. The first eight syllables could not be deciphered. The rest reads as follows: *... ūcāī ke darje mālūm hotā hai [/] dariyāu kā coḍāī māpā jātā hai hor bhī kām nikase he* (?)*,* "[With this scale along the arc] the degrees of height (i.e. of altitude) become known [.] The breadth of rivers can be measured [.] Other tasks also can be performed."

Thus these inscriptions emphasize that the *cāpa-yantra* or double quadrant can be used for astronomical observations as well as for land survey.

On the reverse side, there are three scales along the semi-circular arc. The outermost scale is divided into units of 3º each and is labelled as 3, 6, 9 … 174, 177, 180 from left to right. The middle scale is also calibrated for 3º and labelled as 3, 6, 9 … 174, 177, 180 in the reverse direction, i.e. from the right to the left. The innermost scale is calibrated into single degrees. Inside there are two elaborate tables. Though made in the nineteenth century, this specimen testifies to the fact that the *cāpa-yantra* has been in use throughout the centuries since Brahmagupta mentioned it for the first time in the seventh century.

2.12 Punjabi Astrolabe by Rahīm Bakhsh, VS 1907 / AD 1850 , Private Collection.

This well preserved brass astrolabe has a diameter of 19.5 cm and a height of 24.7 cm and a thickness of 1.2 cm. The maker's inscription is in the Punjabi language and Gurumukhi script. All numerals and legends are in Gurumukhi. These are deeply engraved and filled with black enamel.

The apparatus for suspension consists of a large ornate ring, a simple shackle, an elaborately carved bracket with symmetrical floral pattern in bas relief on both sides. The rim of the main body is graduated in 60 divisions, numbered in Gurumukhi numerals 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 rete is neatly crafted. The ecliptic is divided into 12 signs and labelled as *Mekha, Brikha, Mithana, Karaka, Siṃgha, Kaṃnyā, Tula, Brisacaka, Dhana, Makara, Kuṃbha, Mīna*. Each sign is again subdivided into groups of 6º and labelled as 6, 12, 18, 24, 30. These are further divided into single degrees, but not labelled. The star pointers are shaped as leaves. There are 10 stars outside the ecliptic and 13 stars inside.

Beneath the star map are stacked six plates. On each face of the plates are engraved, besides the latitude for which it has been calibrated, also the names of other proximate localities with their longitudes and latitudes where this plate can be used. The serial number of the clime (*akalīm*) and the governing planet (*satārā*) are also mentioned. This is an unusual feature not found in the astrolabes produced in the Lahore family.

Fig. 16: Punjabi Astrolabe by Rahīm Bakhsh VS 1907 / AD 1850, Private Collection.

For example, on the plate for 30º latitude, the names of two towns are mentioned: Patiala (lat 30;13, long 111;30) and Kurukshetra (lat 30;10, long 112). Here it is the third climate the lord of which is Mars.

On the inner side of the mater the main gazetteer, consisting of names of towns and their latitudes (no longitudes), is engraved continuously in five annular rings. There are altogether (22 + 19 + 14 + 8 =) 54 towns listed.

Fig. 17: Punjabi Astrolabe by Rahīm Bakhsh, VS 1907 /AD 1850, Private Collection.
Inscription on the Back.

On the back, the upper left quadrant has a sine-cosine graph. The upper right quadrant displays a table, showing the lords and essences of the 7 planets. In the two lower quadrants, there are shadow squares: the left for a gnomon of 12 digits (*aṅgula*) and the right for a gnomon of 7 feet (*pāda*). These shadow squares are enclosed by four concentric semi circles, bearing astrological data.

The alidade is simple with two sights, which are rather too close to the centre. The length of the alidade is 19.6 cm, and the distance between the two sights 6.5 cm.

Inside the space provided by the shadow squares is an inscription which reads thus: "This astrolabe (*jaṃtrarāja*) was made by the order of Srī Mahārāje Rājagāna Mahārājedhirāja-Rājesvara-Mahārāje Nareṃdrasiṃgha Mahīṃdra Bahādrajī. [Under] the Seal of the Government of Patiala. Sambat 1907 Caitra sudī 1 Thursday (= Thursday 14 March 1850)."

Below the shadow squares are engraved the names of the designer and the maker in the left and right halves respectively: "He who caused to be made (i.e. he who designed) Jotasī Sī Riṣīkesa. Maker (*kārīgar,* lit. artisan) Rahīm Bakhs."

Why did these people in the Punjab produce naked eye instruments in the nineteenth century when the telescopes were easily available? It is obvious that they did not consider these instruments purely as tools that are discarded the moment an improved variety becomes available, but treated them as important elements of traditional culture which one cultivated, just as one cultivates still, say, versification in Sanskrit. And the local Maharajas, of Kaputhala, Patiala and other principalities, patronized these endeavours. Thus Dharam Chand and his circle of learned instrument makers kept alive what must have been once a vigorous tradition of instrument making, and in this process also created entirely new varieties, such as the plate with multiple horizons. In this Punjabi astrolabe, called in India appropriately as *Yantrarāja,* we see the traditions of instrumentation as practiced by different culture groups coming together in a most harmonious way, with the Sikh prince Maharaja Narinder Singh as the patron, the Hindu astrologer Rishikesh as the designer, and the Muslim artisan Rahim Bakhsh as the maker.

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Abbreviations used:

IJHS = *Indian Journal of History of Science,* New Delhi.

SHMS= *Studies in History of Medicine and Science,* New Delhi.

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