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YANTRARĀJA : THE ASTROLABE IN SANSKRIT

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The astrolabe, originally invented in Hellenistic antiquity, attained its highest popularity in the Islamic world, from where it was transmitted westwards to Europe and eastwards to India. It may have been introduced into India by Al-Bīrūnī in the eleventh century. Its manufacture, however, commenced only in the latter half of the fourteenth century under Fīrūz Shāh Tughluq. Fīrūz also sponsored the composition of manuals on the astrolabe in Persian and Sanskrit.

The astrolabe was received enthusiastically by Hindu *jyotiṣīs*, who called it the "king of instruments". Their response is two-fold: first several manuals were composed on the construction and use of the astrolabe in Sanskrit; second, actual astrolabes were also produced on which legends were engraved in Sanskrit language and in Devanāgarī script. This paper offers an overview of these two types of documents, which are important for the history of scientific instrumentation in India.

Key words : Astrolabe, Fīrūz Shah Tughluq, Indo-Persian astrolabe, Mahendra Sūri, Northern astrolabe, Padmanābha, Rāmacandra, Sanskrit astrolabe, Southern astrolabe, Universal Zarqālī astrolabe, *Yantraprakāśa*, *Yantrarāja*, Sawai jai Singh.

0.1 The astrolabe is a highly sophisticated astronomical instrument of the pre-modern times. In the Middle Ages, it enjoyed a reputation comparable to that reserved today for the personal computer. It is a versatile observational and computational instrument. As an observational instrument, it was employed for measuring the altitudes of the heavenly bodies and also for measuring the heights and distances in land survey. As a computational device, it can be made to simulate the motion of the heavens at any given locality and time. It can also be used as an analog computer for solving numerous problems in spherical trigonometry. Therefore, the astrolabe was rightly termed as the "Universe within one's palm."[1]

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The invention of the astrolabe is usually attributed to Hipparchus of the second century BC. But there is no firm evidence to support this view. It is however certain that the instrument was well known to the Greeks before the beginning of the Christian era. Even so, the astrolabe reached its highest perfection and popularity in the Islamic world. Muslim astronomers contributed several treatises on the science of the astrolabe. They also transmitted the knowledge of the astrolabe to Europe in the west and to India in the east.

0.2 It is not known when exactly the astrolabe reached India. Al-Bīrūnī claims, in his *Indica*, to have composed a manual on the astrolabe in Sanskrit verse.[2] Whether true or not,[3] there is no denying the fact that he discussed the astrolabe and its variants in several of his works.[4] Therefore it is entirely probable that he brought the astrolabe with him and taught its working principles to the Hindu *jyotiṣīs* at Multan in the first quarter of the eleventh century. With the establishment of the Sultanate in Delhi in the next century, Muslim scholars began to migrate in great numbers to Delhi. Some of these brought astrolabes and employed them for teaching astronomy or for astrological purposes. Since astronomy formed a regular part of Muslim education, ability to use the astrolabe was expected of every good scholar. A few thirteenth century astrolabes from the Middle East are still extant in Indian collections, which must have been brought here by the immigrant scholars.

In the latter half of the fourteenth century, Fīrūz Shāh Tughluq promoted the study of the astrolabe.[5] He not only got several astrolabes manufactured at Delhi—probably for the first time in India—he also encouraged the composition of manuals on the construction and use of the astrolabe both in Persian and in Sanskrit. During the next five hundred years up to the end of the nineteenth century, a large number of astrolabes were manufactured in India with Arabic / Persian legends. These are generally classified as Indo-Persian astrolabes. I have discussed this class of astrolabes elsewhere in greater detail.[6]

0.3 In this paper, I wish to examine the response of Hindu and Jaina *jyotiṣīs* to this remarkable instrument imported from the Islamic world. Their response was twofold: first, several manuals were composed in Sanskrit on the construction and use of the astrolabe. Secondly, this activity of composition was accompanied by the manufacture of astrolabes on which the legends were engraved in Sanskrit language and in Devanāgarī script. I classify this group as "Sanskrit astrolabes".

Between 1370 and 1870, at least fifteen manuals were composed in Sanskrit which discuss the astrolabe either exclusively or as one of the several astronomical instruments. The Sanskrit astrolabes that still survives do not go that far back. The earliest extant Sanskrit astrolabe was crafted in Gujarat in 1607 and the latest that I saw was manufactured in Rajasthan most probably in 1902. Between these two lie some seventy astrolabes which are either extant or for which there are records.

0.4 This impressive number of Sanskrit manuals and Sanskrit astrolabes produced during the half millennium from 1370 to the end of the nineteenth century makes it abundantly clear that the Indian *jyotiṣīs* were greatly impressed by this versatile instrument. In fact, no other foreign idea or object enthused Indian pundits in pre-modern times as much as the astrolabe seems to have done.

0.5. In the following pages, I present first as overview of the literature on the astrolabe in Sanskrit[7] and then of the extant specimens of the Sanskrit astrolabes. Some of these Sanskrit texts and several of the signed Sanskrit astrolabes will be taken up for detailed study in my forthcoming publications, as part of an ongoing INSA project on "A Descriptive Catalogue of Indian Astronomical and Time-Measuring Instruments".

1.1 Of the significant contribution made by the Jainas to the intellectual history of India, an important but not so well explored aspect is their role as mediators between the Islamic and Sanskritic traditions of learning.[8] After the establishment of the Sultanate of Delhi, a number of Jaina monks and laymen cultivated good relations with the Delhi court. One of these was Mehendra Sūri, the author of the first ever manual on the astrolabe in Sanskrit.[9] The credit for sponsoring this manual, as has been stated above, goes to Fīrūz Shāh Tughluq. Under his patronage, Mahendra Sūri produced the manual in 1370—at about the same time as Geoffrey Chaucer wrote his *Treatise on the Astrolabe* in English. The Sūri was so impressed by the versatile functions of the astrolabe that he called it *yantrarāja*, "the king of astronomical instruments", and it is under this name that the astrolabe came to be known in Sanskrit since then. Accordingly his manual bears the tittle *Yantrarājāgama* or simply *Yantrarāja*.[10] His pupil Malayendu Sūri[11] wrote a commentary on this work in about 1382. From Malayendu we learn that his teacher Mahendra Sūri was the foremost astronomer at Fīrūz's court (*śrīpīrojaśakendrā sarvagaṇkā-praṣṭo mahendraprabhuḥ*).[12] There are two other commentaries on this *Yantrarāja*, by Gopīrāja written in 1540,[13] and by Yanjñeśvara in 1842.[14]

The text is divided into five chapters. The first chapter *Gaṇitādhyāya* provides various trigonometrical parameters needed for the construction of the astrolabe. The second chapter called *Yantraghaṭanādhyāya* enumerates the different parts of the astrolabe. The construction of the common northern astrolabe (*saumya-yantra*) and other variants is described in the third chapter named *Yantraracanādhyāya*, while the next *Yantraśodhanādhyāya* explains the method of verifying whether the astrolabe is properly constructed or not. The final and the fifth chapter, entitled *Yantravicāraṇādhyāya* discusses the use of the astrolabe as an observational and computational instrument and dwells on the various problems in astronomy and spherical trigonometry that can be solved by means of the astrolabe.[15]

At the beginning of his work, Mehendra says that the Muslims (*yavana*) have written many treatises on the astrolabe. Having extracted their essence, just as one

extracts nectar after churning the milky ocean, he is presenting this work in Sanskrit.[16] We do not know exactly what these Arabic /Persian sources were which Mahendra Sūri consulted, but they certainly must have included Al-Bīrūnī's various Arabic writings on the astrolabe and also Al-Marrākushī's thirteenth century treatise on the astronomical instruments.[17]

In the same year when Mahendra Sūri wrote the *Yantrarāja*, there appeared also the Sīrat-i-Fīrūz Shāhī, an anonymous chronicle of the reign of Fīruz Shāh Tughluq.[18] In one of its chapters, the chronicle describes in great detail Fīruz's interest in the astrolabe and the various astrolabes he got manufactured at Delhi. There is a great correspondence between this account and that in Mahendra Sūri's *Yantrarāja*. This fact suggests that Mahendra Sūri and the unnamed Muslim astronomers at Fīrūz's court were working in close cooperation.

Therefore it is not surprising that, following the Persian *Sīrat*, the Sanskrit *Yantrarāja* also discusses two lesser known variants of the astrolabe. The most common variety of astrolabe is the so called northern astrolabe (Arabic: *asṭurlāb shumālī;* Sanskrit: *saumya-yantra*). Here the rete is projected from the south celestial pole and displays a map of the northern celestial hemisphere, extending upto the Tropic of Capricorn. Therefore, with this type of astrolabe, the orientation is done at night by means of stars situated to the north of the Tropic of Capricorn. As against this, the southern astrolabe (Arabic : *asṭurlāb janūbī;* Sanskrit : *yāmya-yantra*) displays the southern celestial hemisphere and here orientation is done by means of those stars that lie to the south of the Tropic of Cancer and are visible in the northern temperate zone of the earth. The third variant combines the features of these two and is called *Asṭurlāb Shumālī wa Janūbī* (Sanskrit : *miśra-yantra*). For constructing the north-south astrolabe, Malayendu provides in his commentary elaborate tables of eccentricities (*kendra*) and radii (*vyāsārdha*), in northern and southern hemispheres, at six degree intervals of altitudes, for six different localities[19]

1.2 At the beginning of the fifteenth century, Padmānabha[20] devoted the first chapter *Yantrarājādhikāra* of his *Yantrakiraṇāvalī* to the astrolabe. Strangely enough, Padmanābha does not discuss in this chapter the common northern astrolabe but the rather unusual southern astrolabe.[21]

1.3 In 1428, Rāmacandra Vājapeyi[22] discussed the astrolabe quite extensively in his *Yantraprakāśa*,[23] which he composed at Pātrapuñjanagara, near modern Lucknow in U.P. The *Yantraprakāśa* describes the construction and use of some thirty-five astronomical instruments—perhaps the largest number ever dealt with in a Sanskrit work. The major part of this work is devoted to the astrolabe, which is called here *Sulabhā*, another significant name meaning that with this instrument several types of measurements become easy. Rāmacandra expressly declares that if one knows the science of the astrolabe well, the entire universe will become comprehensible like the myrobalan on one's palm (*yasmin karāmalakavad vidite viditaṃ bhaved viśvam*).[24]

Though Rāmacandra does not mention Mahendra Sūri by name, his familiarity with the latter's *Yantrarāja* and also with Malayendu's commentary is clearly discernible in his work. Rāmacandra appears to have a genuine interest also in the practical aspect of instrument making. He discusses not only the theory of the astrolabe but dwells also on the various tools and devices needed in its manufacture.

1.4 In this century, the science of the astrolabe seems to have reached Kerala as well. In his commentary entitled *Siddhāntadīpikā* composed in 1432 on the *Mahābhāskarīya,* Parameśvara[25] uses the shadow squares at the back of the astrolabe to measure the altitude of the eclipsed body. Here Parameśvara gives the altitudes in terms of the shadows of a gnomon of 6 feet (*padabhā*).[26] This is rather unusual because the Sanskrit astrolabe usually contain shadow squares for only gnomons of 7 digits (*saptāṅgulaśaṅkucchāya*) and of 12 digits (*dvādaśāṅgulasaṅkucchāyā*) as against the shadow squares respectively for 7 feet and for 12 digits in the Islamic astrolabes. Thus it is likely that Parameśvara's knowledge of the astrolabe is based on a tradition that is different from the one prevailing in western and northern India.

1.5 We have noted the role of the Jaina monk Mahendra Sūri as mediator between the Islamic and Sanskritic tradition of learning. About the end of the fifteenth century, another Jaina monk, Muni Megharatna, pupil of Vinayasundara of Vaṭagaccha, wrote the *Usturalāvayantra* in 38 stanzas, with many Arabic-Persian technical terms. The unique manuscript copy at the Anup Sanskrit Library of Bikaner contains also commentaries in Sanskrit and Rajasthani.[27]

1.6 Three seventeenth century texts discuss the astrolabe along with other instruments. In 1615 Viśrāma[28] of Jambūsāra devoted the third chapter of his *Yantraśiromaṇi* to the astrolabe.[29] In 1621 Nṛsiṃha Daivajña [30] of Kāśī discussed the astrolabe in his *Vāsanāvārttika* on the *Siddhāntaśiromaṇi* quoting extensively from works of Mahendra and Rāmacandra.[31] In 1639 Nityānanda[32] devoted the *Yantrādhyāya* of his *Sarvasiddhāntarāja* mainly to the astrolabe. Like Mahendra Sūri, Nityānanda also divides his discussion of the astrolabe in five chapters and names them in a similar fashion, viz. *Gaṇitādhyāya, Ghaṭanādhyāya, Racanādhyāya, Śodhanādhyāya* and *Yantranirīkṣaṇādhyāya.*[33]

1.7 In the early eighteenth century, the study of the astrolabe received a great impetus under Sawai Jai Singh. [34] Jai Singh immediately saw the advantages of the astrolabe as a teaching tool, although for observational purposes he preferred large scale instruments in masonry. He collected a number of exquisitely crafted Mughal, i.e. Indo-Persian astrolabes. He also established a manufactory of Sanskrit astrolabes.[35] He himself composed or caused to be composed four manuals on the astrolabe in Sanskrit. Like the Arabic and Persian scientific texts, all the four are written in prose. Thus Sawai Jai Singh Sanskrit scientific writing was attempted for the first time in prose, abandoning the traditional verse form.

The first of these is entitled *Yantraprakāra*. It is a compilation of material on various astronomical instruments prepared during the early stages of Jai Singh's researches in astronomy from diverse sources including Ptolemy's *Almagest*. The eighth section of this work explains the use of the astrolabe rather briefly.[36] But a more detailed treatment of the astrolabe is available in the *Yantrarājaracanā*, attributed to Jai Singh. Here the astronomer- king makes an excellent presentation of the theory of the astrolabe. While Mahendra Sūri provides mathematical proofs for his propositions, Jai Singh offers geometrical proofs.[37]

One of the Mughal astrolabes by Jai Singh belongs to a special variety known as the "Universal Zarqālī Astrolabe." The original prototype was invented by Ibn al-Zarqallu̇ at Toledo in the eleventh century. The Mughal specimen acquired by Jai Singh was crafted by Dīyā' al-Dīn Muḥammad in 1681 at Delhi. It is a very large astrolabe measuring some 555 mm in diameter.[38] After acquiring this precious astrolabe, Jai Singh caused the composition of a Sanskrit manual entitled *Sarvadeśīyā Jarakālī Yantra* on the construction and use of this instrument.[39]

In the Islamic world and also in India, Naṣīr al-Dīn Muḥammad al-Ṭūsī's (1201-1274) Persian manual on the astrolabe entitled *Risālat al-uṣturlāb* enjoyed great popularity. Since it consists of twenty chapters, it is commonly known as the Bīst Bāb ("Twenty Chapters").[40] Under Jai Singh's orders, this work was translated into Sanskrit with the title *Yantrarājā-vicāra-viṃśādhyāyī*.[41] The Sarasvati Bhavan Library of the Varanasi Sanskrit University possesses an interesting manuscript which contains the Persian text of the *Bīst Bāb* but in Devanāgarī script.[42] I am inclined to think that this transliteration was also produced at Jai Singh's court for some pundit who understood Persian but could not read the script.

1.8 Even after Jai Singh's time, the astrolabe continued to be discussed in several Sanskrit works. Śrīnatha Chagāṇi prepared a short metrical version in 29 verses of Jai Singh's *Yantrarājaracanā* with the title *Yantraprabhā*.[43] In 1772 Nandarāma [44] composed the *Yantrasāra* in which the astrolabe was discussed along with other instruments.[45] Ten years later, in 1782, Mathurānātha Śukla[46] produced at Varanasi the *Yantra-rāja-ghaṭanā* also known as *Yantrarājakalpa*. Mathurānātha, who later became a teacher of astronomy in the Benares Sanskrit College founded by Jonathan Duncan, was a good scholar of Persian as well. In this work, Mathurānātha teaches the construction of all the three varieties of astrolabes—the northern, southern and the mixed—with the aid of detailed diagrams.[47] Finally in the second half of the nineteenth century, Bāpudevaśāstrin [48] is reported to have prepared *Yantrarājopayogi-chedyaka* (projections or drawings useful for the astrolabe),[49] but no manuscript has come to light so far.

2.0 Mere manuals on the astrolabe do not serve much purpose unless there are actual specimens with which one can put the theory into practice. As early as 1790, one

Reuben Burrow noticed a Sanskrit astrolabe brought to him by Mackinnon from Jaipur.[50] Soon Sanskrit astrolabe began to be collected by various employees of the East India Company, including H.H. Wilson, who later became the first Boden Professor of Sanskrit at the University of Oxford in 1832. Some of these astrolabes were studied by W.H. Morley in an appendix to his *Description of a Persian Astrolabe constructed for Shāh Husain Safawī*[51] in 1856. In this century, Kaye and others discussed Sanskrit astrolabes along with other instruments. Writing in 1985, Dr. Emilie Savage Smith remarks in her exemplary study of the *Islamicate Celestial Globes* that "eight Sanskrit astrolabes are known to exist."[52] My investigation happily raises the number to about 70 for which records of references are available. Of these I have personally examined more than thirty.

2.1 It may be assumed that with Mahendra Sūri's composition of the first Sanskrit manual in 1370, the production of Sanskrit astrolabes also must have commenced. But they did not survive the vagaries of time and climate. Of those that are extant, the earliest known Sanskrit astrolabe is dated Saṃvat 1663, Śāka current 1528, Māgha vadi 1 Sunday, corresponding to 1 February 1607. The inscription on the astrolabe goes on to say that it was manufactured at Ahmedabad during the reign of Salim Shah, i.e., Jahāngīr, for the use of Dāmodara, son of Caṇḍīdāsa.It is a large piece with a diameter of 276 mm. There are six tympans (*akṣapatra*) calibrated for the latitudes of 12 different localities ranging from Bijapur (18°) in the south to Kashmir (35;20°) in the north. It is now in a private collection at Brussels. Doubts have been expressed about its authenticity. I have examined it very carefully and compared with three other Sanskrit astrolabes produced in the seventeenth century. I am convinced that it is genuine except for the crude star map (*bhapatra*) which is clearly a late replacement.[53]

2.2 Chronologically the next Sanskrit astrolabe is now at the Royal Scottish Museum of Edinburgh. It is dated Saṃvat 1700 Caitra kṛṣṇa 11, which corresponds to 2 April 1644. The inscription records that it was caused to be made for one Maṇirāma. Subsequently one Līlānātha Jyotirvid owned it. This fact is recorded in a different hand. The astrolabe measures 128 mm in diameter. It also contains six tympans for 12 different localities. This astrolabe is in an excellent state of preservation.

2.3 The next astrolabe for which we have records was manufactured on Friday, Śaka1591 current Āsvayuja sudi 1, which corresponds to 12 October 1668, for Rāghavajit, son of Daivajña Viśvanātha. In 1936, this astrolabe belonged to Kṛṣṇśaṃkara Keśavarāma Raikva of Surat, who reproduced several drawings of this astrolabe and its various components in his edition of Mahendra Sūri's *Yantrarāja*[54] (Fig. 1). In his introduction to the *Yantrarāja*, Raikva mentions that he had in his collection also a manuscript of Mahendra Sūri's *Yantrarāja* which the same Rāghavajit had copied in Śaka 1590, i.e. just a year before the astrolabe was manufactured. Unfortunately, the present location of his historically important astrolabe is not known, nor of the manuscript.

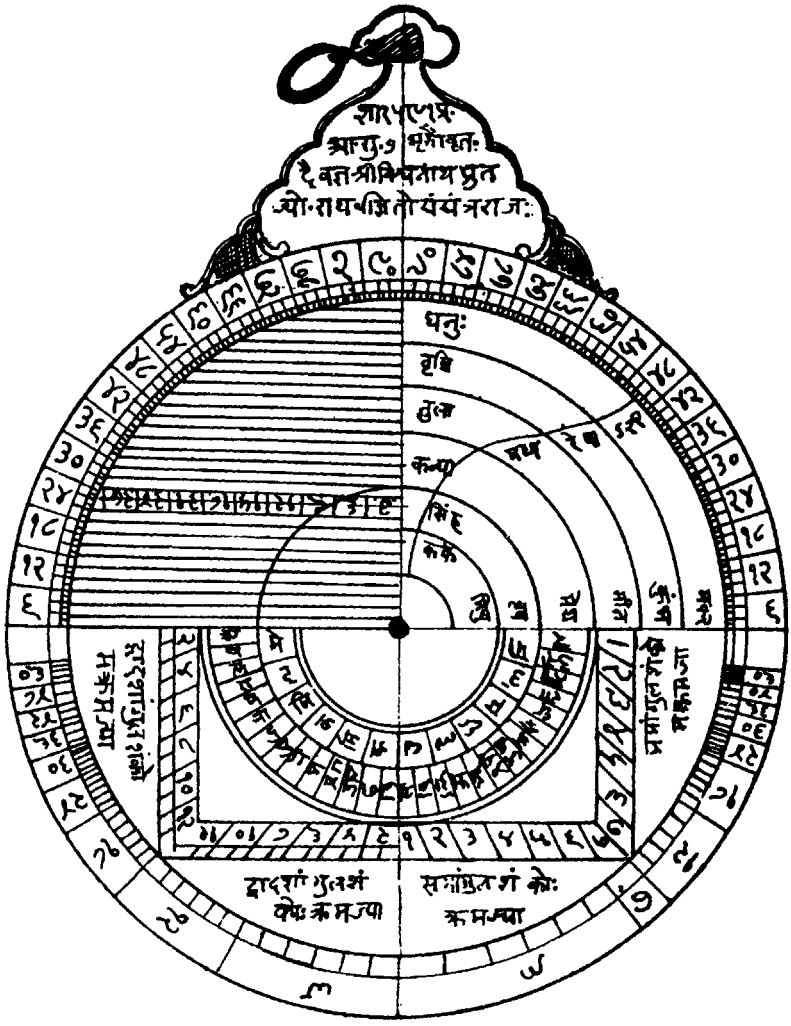

Fig. 1. Rāghavajit's Sanskrit Astrolabe with five tympans, AD 1668. Back with the inscription engraved on the suspension bracket at the top. (From K. K. Raikva's edition of the *Yantrarāja.*)

2.4 The pitt Rivers Museum of Oxford has one astrolabe which was produced on Tuesday, Saṃvat 1730 kārtika sudi 6, corresponding to 17 October 1673, for the astrologer Indrajīka or Indrajī. With a diameter of 115 mm, it has five tympans on which projections are engraved for 8 different localities.[55]

2.5 As mentioned above, in the early eighteenth century Sawai Jai Singh established a *kārkhānā* for the manufacture of Sanskrit astrolabes. Here he caused the manufacture of some ornate astrolabes with multiple tympans, designed after the Mughal Indo-Persian astrolabes. He, however, popularized simple astrolabes with a single tympan calibrated to the latitude of Jaipur at 27°(See Fig. 2). It appears that a

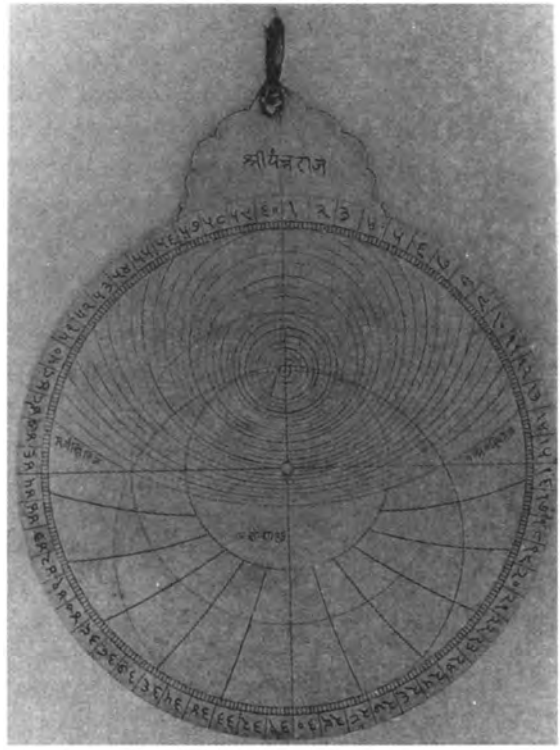

Fig.2. A Sanskrit astrolabe with a single tympan calibrated for the latitude of 27° N. Note the name *Śrīyantrarāja* engraved on the suspension bracket at the top and the latitude *akṣāṃśa* 27 engraved in the middle. Present location unknown. Archive photo: Courtesy, The Museum of the History of Science, Oxford.

large number of such astrolabes were produced and distributed among the *Jyotiṣis* of his court, so that they all became proficient in the science of the astrolabe. In the stores of Jai singh's Observatory at Jaipur, I discovered a number of unfinished astrolabes belonging to this *kārkhānā*. After Jai Singh's death, this manufactory seems to have shifted to Kūcamaṇa, a little to the west of Jaipur but on the same latitude. This place produced a number of interesting astrolabes.

2.6 Astrolabes were also crafted at other towns of Rajasthan, such as Bundi. Here was produced an enormous astrolabe measuring 662 mm which is now with the Science Museum of London. The astrolabist Śivalāla completed this on Sunday, 25 December 1870 to coincide with the birthday of the ruling prince Rāmasiṃha. On the back of this astrolabe was engraved the entire fifth chapter of Mahendra Sūri's *Yantrarāja* (See Fig.3). This mammoth piece could certainly not be used for observations. It was meant purely as a teaching aid to supplement the study of the text. But this instrument also incorporates the operational part of the text itself. Thus we have made a full circle by starting from Mahendra's text on the as astrolabe and coming back to the same text this time engraved on an astrolabe. Sanskrit astrolabes continued to be produced in Rajasthan even up to 1902. A specimen made in this year is in a private collection at Paris.

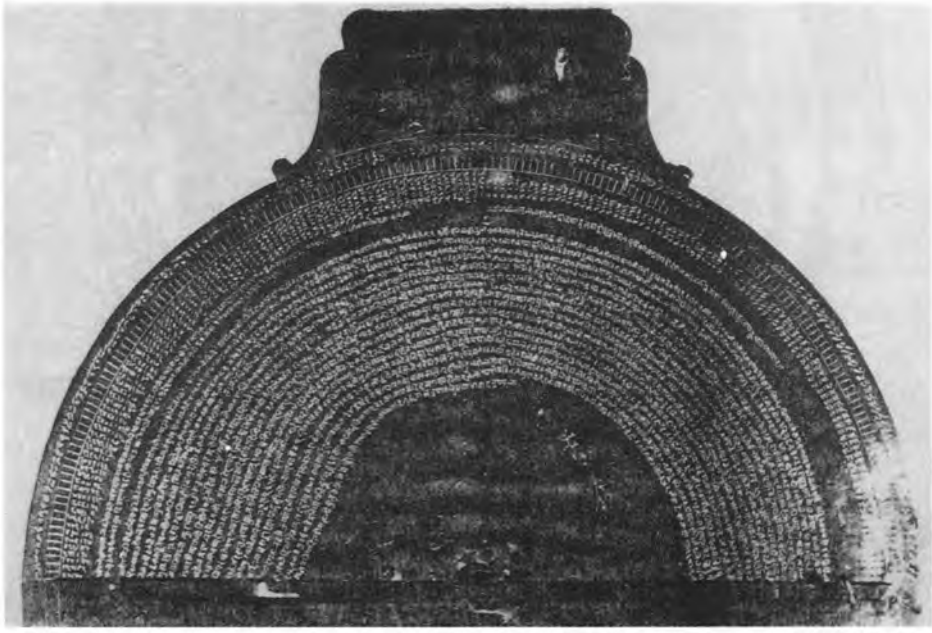

Fig. 3. Sanskrit astrolabe manufactured by Śivalāla in 1879 for the latitude of Bundi at 25;30° N. The entire fifth chapter of Mahendra Sūri's *Yantrarāja* is engraved in the two upper quadrants at the back. Photo: Courtesy, The Science Museum, London.

2.7 The astrolabe thus played an important role in the history of science in medieval India both as an observational and computational device, and as a graphic teaching tool and testifies to the Indian astronomer's receptivity to valuable concepts from the outside. A full account of the history of this instrument in India together with descriptions of all extant specimens produced in India will appear in the final report of the present project.

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APPENDIX : SANSKRIT TEXTS ON THE ASTROLABE

Mahendra Sūri, *Yantrarāja* 1370 AD.
Padmanābha, *Yantrakiraṇāvalī*, 1423.
Rāmachandra Vājapeyin, *Yantraprakāśa*, 1428.
Parameśvara, *Siddhāntadīpikā on the Mahābhāskarīya*, 1432.
Megharatna Muni, *Usturalāvayantra*, end of 15th c.
Visrāma, *Yantraśiromaṇi*, 1615.
Nṛsiṃha Daivajña, *Vāsanāvārttika* on the *Siddhāntaśiromaṇi*, 1621.
Nityānanda, *Sarvasiddhāntarāja*, 1639.
Anon, *Yantraprakāra*, ca. 1724-40.
Jayasiṃha, *Yantrarājaracanā*, ca. 1724-1740.
Anon, *Sarvadesīya-jarakālī-yantra*, ca. 1724-1740.
Anon, *Yantrarājavicāraviṃśādhyāyī*, ca. 1724-1740.
Śrīnātha Chagāṇī, *Yantraprabhā*.
Nandrāma, *Yantrasāra*, 1772.
Mathurānātha Śukla, *Yantrarājaghaṭanā* or *kalpa*, 1782.
Bāpudevaśāstrin, *Yantrarājopayogi-chedyaka*, mid 19th c.

NOTES AND REFERENCES

ABBREVIATIONS USED :

CESS = Pingree, David. *Census of the Exact Sciences in Sanskrit, Series A*, Vol. 1: 1970; Vol. 2: 1971; Vol. 3: 1976; Vol. 4: 1981; Vol. 5: 1994; all published from Philadelphia.

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

1 The literature on the history, construction and principles of the astrolabe is quite vast. The best introduction is Hartner, Willy, The principles and Use of the Astrolabe, in: idem, *Oriens-Occidens*, [Vol. I], Hildesheim 1985, pp. 287-311. For its history in India, see Sarma, Sreeramula Rajeswara, Astronomical Instruments in Mughal Miniatures, *Studien zur Indologie und Iranistik*, 1992, **16**, pp. 235-276; idem, Indian Astronomical and time-Measuring Instruments: A Catalogue in Preparation, IJHS, 1994, **29**(4)pp. 507-528; and Ohashi, Yukio, Early History of the Astrolabe in India, IJHS, 1997, **32**(3)pp. 199-295.

2 Cf. Sachau, Eduard (tr), *Alberuni's India, first Indian reprint:* New Delhi 1964, Vol. I, p. 13.

3 Doubts were cast on his knowledge of Sanskrit; cf among others, Pingree, David, Al-Bīrūnī's Knowledge of Sanskrit Astronomical Texts, in: Chelkovski, Peter J. (ed), *The Scholar and the Saint,* New York 1975, pp. 67-81.

4 Cf. Sarma, Sreeramula Rajeswara, "Sulṭān, Sūri and the Astrolabe," to appear in *Professor Mohammed Habib Commemoration Volume.I*

5 On Fīrūz's interest in the astrolabe, see ibid.

6 Sarma, Sreeramula Rajeswara, The Lahore family of Astrolabists and their Ouvrage, SHMS, 1994, **13**(2) pp. 205-224.

7 For the sake of clarity, a list of these texts is given in the Appendix.

8 I have argued this point in Sarma, Sreeramula Rajeswara, Sanskrit Manuals for Learning Persian, in: Safavi, Azarmi Dukht (ed), *Adab Shenasi,* Aligarh, 1996,pp. 1-12.

9 Cf. CESS, A-4, 393-395; A-5,296.

10 Raikva, Kṛṣnasaṃkara Keśavarāma (ed), *Yantrarāja of Mahendra Sūri, together with the commentary of Malayendu Sūri and Yantraśiromaṇi of Viśrāma,* Bombay 1936.

11 Cf. CESS, A-4, 363-364; A-5, 282-3.

12 In a common stanza that occurs at the conclusion of his commentary on each of the five chapters.

13 Cf. CESS, A-2,133.

14 Cf. ibid, A-5, 318-319. I have used MS BORI 556 of 1899-1915.

15 Cf. also Ohashi, op.cit., pp. 211-216.

16 *Yantrarāja,*i.3.

17 Professor David Pingree informs me that the table of the day-sines in Mahendra Sūri's *Yantrarāja* (pp. 11-15) is derived from Al-Marrākushī. For the latter, cf. Śedillot, *Jean-Jacques and Louis-Amélie, Traité des instruments astronomiques des Arabs,* Paris, 1834; reprint: Frankfurt, 1984, pp. 349-350.

18 The unique copy of this chronicle is preserved in the Khuda Bakhsh Oriental Public Library, Patna. I had consulted the unpublished English translation by Professor Syed Hasan Askari. Cf. also Sarma, Sulṭān, Sūri and the Astrolabe (n. 4).

19 Ibid, pp. 19-25, These localities are Tilaṅga (latitude 18°), Tryamabaka (21°), Aṇahillapattana (24°), Dillī (28° 39') and Nepāla (31°).

20 Cf. CESS, A-4, 170-172; A-5, 205.

21 It is unusual because, of the three thousand and odd Islamic, European and Indian astrolabes that are extant today in different parts of the world, there are hardly a dozen southern astrolabes. In his Early History of the Astrolabe in India (n. 1), Dr. Yukio Ohashi offers a fine edition, translation and commentary of Padmanābha's *Yantrarājadhikāra.*

22 Cf. CESS, A-5, 467-479.

23 Together with an auto-commentary, available in MS G-1363 of the Asiatic Society, Calcutta and MS 975/1886-92 of the Bhandarkar Oriental Research Institute, Poona.

24 *Yantraprakāśa* 1.9.

25 Cf. CESS, A-4, 187-192.

26 Cf. *Mahābhāskarīya of Bhāskarācārya* with the Bhāṣya of Govindasvāmin and the Super- commentary *Siddhāntadīpikā* of Parameśvara, ed. T. S. Kuppanna Sastri, Madras 1957, pp. 330-331. Professor David Pingree kindly drew my attention to this passage.

27 Agar Chand Nahata, "Ustaralāva Yantra Sambandhī ek Mahattvapūrṇa Jaina Grantha," *Jaina-siddhānta-bhāskara,* vol.18(2)pp. 119-128.

28 Cf. CESS, A-5,658.

29 Raikva, Kṛṣṇaśaṃkara Keśavarāma (ed), *Tantrarāja of Mahendra Sūri together with the Commentary of Malayendu Sūri, and Yantraśiromaṇi of Viśrāma,* Bombay 1936,pp. 102-113.

30 Cf. CESS, A-3, 204-206.

31 Caturvedi, Murali Dhara (ed), *Siddhāntaśiromaṇi of Bhāskarācārya with the Vārttika of Nṛsiṃha Daivajña,* Varanasi, 1981, pp. 445-458.

32 Cf. CESS, A-3, 173-174; A-4, 141; A-5,184.

33 Cf. Velankar, H.D., *A Descriptive Catalogue of the Sanskrit and Prakrit manuscripts in the Collection of the Asiatic Society of Bombay,* second edition, edited by V.M. Kulkarni and Devangana Desai, Mumbai, 1998,pp. 88-89, MS 264: *Sarvasiddhāntarāja (Yantradhyāya)* of Nityānanda.

34 CF. CESS, A-3, 63-4; A-5,117-118.

35 Some of these portable instruments, either collected by Jai Singh or manufactured under his orders, still survive in Jaipur. The Department of Archaeology and Museums, Government of Rajasthan, has recently constructed a separate building in the premies of the Jantar Mantar Observatory, Jaipur, to display these instruments.

36 Sarma, Sreeramula Rajeswara(ed and tr),*Yantrapakāra of Sawai Jai Singh,* Supplement to SHMS, 1986-87, **10-11**, supplement; on the astrolabe, cf. pp. 20-21, 61-63.

37 Kedāranātha Jyotirvid (ed),*Yantrarājaracanā of Jayasiṃhadeva and Yantraprabhā of Śrīnātha,* Jaipur 1953.

38 Cf. Sarma, Sreeramula Rajeswara , The Ṣafīḥa Zarqāliyya in India, in: Casulleras, Josep and Samsó, Julio (ed) , *From Baghdad to Barcelona: Studies in Islamic Exact Sciences in Honor of Prof. Juan Vernet,* Barcelona 1996,pp. 718-735; see also Kaye, G.R., *The Astronomical Observatories of Jai Singh,* Calcutta, 1918, pp. 27-30.

39 The text is inserted in the middle of the Spaṣṭādhikāra in: Caturveda, Muralīdhara (ed), *Siddhāntasamrāṭ, Jagannātha-Samrāḍ-viracitaḥ,* Sagar, 1976,pp. 96-105. I have also used the manuscripts at Maharaja Sawai Mansingh II Museum, Jaipur, Khas Muhar 5483; Trinity College, Cambridge, R. 15.139, ff. 1-8; BORI, Poona, No. 557 of 1899 / 1915.

40 Cf. CESS, A-3, 145; A-4, 125.

41 Bhaṭṭācārya, Vibhūtibhūṣaṇa (ed), *Yantrarāja-vicāra-viṃśādhyāyī by Nayanasukha Upādhyāya,* Varanasi 1979. However, as I have shown elsewhere, Bhaṭṭācārya's description of this translation to Nayanasukha is based on doubtful evidence. Cf. my "Translation of Scientific text into Sanskrit under Sawai Jai Singh," to appear in *Sri Venkateswara University Oriental Journal,* 1999, **42**.

42 Ms. U 34568 catalogued under the title *Yantrarājaprayogaḥ.*

43 This text is published with Jai Singh's *Yantrarājaracanā* (see n. 37 above) on pp. 17-19.

44 Cf. CESS, A-3,128-130; A-5, 156-158.

45 I have used MS BORI 851 of 1884-87 copied in 1802 and 504 of 1892-95 copied in 1830.

46 Cf. CESS, A-349-350.

47 MS, U 35245 of the Sanskrit University, Varanasi. In this manuscript, several of the diagrams are incomplete.

48 Cf. CESS, A-4, 241-242; A-5, 232; Cf. also Sarma, Sreeramula Rajeswara, Sanskrit as Vehicle for Science: Lancelot Wilkinson's Efforts in the 1830's, SHMS, 1995-96, **14**, pp. 189-199.

49 Thus Śankara Bālakṛṣṇa Dīkṣita in his *Bhāratīya Jyotiṣa,* tr. in Hindi by Śivanātha Jhārakhaṇḍī, 2nd edition, Lucknow 1963,p. 411.

50 Cf. Burrow, Reuben, A proof that the Hindoos had the Binomial Theorem, *Asiatick Researches,* 1770, **2**, pp. 486-497, esp. 488-489. Finding that the astrolabe from Jaipur exactly corresponds to the description given by Chaucer in his treatise and having just heard about the Vedas that they contain all knowledge, Burrow drew the fantastic conclusion that Chaucer's *Treatise on the Astrolabe* may have been translated from the Veda! I refrain from quoting this naive gentleman; far too many people are already looking for just this kind of endorsement from a westerner about the "scientific content" of the Veda.

51 Reprinted in Gunther, Robert T. *Astrolabes of the World,* Oxford 1932, Vol. I, pp. 1-47. Appendix, No. 1, is on pp. 32-46.

52 *Islamicate Celestial Globes: Their History and Construction* and Use, Washington, DC, 1985, p. 304, n. 181.

53 This astrolabe was formerly at the Time Museum, Rockford, USA. For a detailed description, see Turner, A.J. , *The Time Museum, Catalogue of Collections,* Vol. I, part 1) Astrolabes, Astrolabe-related Instruments, Rockford 1985, No. 15, pp. 120-123. In 1988, it was sold through the Christie's, South Kensington, London; Cf. their auction catalogue *From the Time Museum, Time Measuring Instruments,* 14 April 1988, item no. 157, pp. 98-99. The present owner very kindly allowed me to study this astrolabe at Brussels in February 1996. I shall discuss this and the other seventeenth century Sanskrit astrolabes in a forthcoming paper.

54 See no. 10 above; three of these drawings are reproduced here as Figures 1,2 and 3.

55 A brief description of this astrolabe appeared in Gunther, R. T. *Early Science at Oxford, Oxford,* 1923, Vol. II, pp. 279-280. See also idem, *The Astrolabes of the World,* Oxford 1932, Vol. I, No. 79, p. 211, Fig. 110.

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