4.6 A NOTE ON SOME SANSKRIT MANUSCRIPTS ON ASTRONOMICAL INSTRUMENTS

Yukio Ohashi (Visiting Scholar)
Dept. of Mathematics, University of Lucknow, Lucknow, India.
(Permanent address: 3-5-26 Hiroo, Shibuya-ku, Tokyo, Japan)

INTRODUCTION

The earliest astronomical instruments in India are the *śaṅku* (gnomon) and the *ghaṭikā* (clepsydra). The former is mentioned in the Śulbasūtras, and the latter in the *Vedāṅgajyotiṣa*. *Āryabhaṭa* described a rotating model of the celestial sphere. After *Āryabhaṭa*, several instruments were described by Varāhamihira, Brahmagupta, Lalla, Śrīpati, and Bhāskara II. After Bhāskara II, some Sanskrit texts specialized on astronomical instruments were composed. The earliest text of this kind is the *Yantra-rāja* (AD 1370) written by Mahendra Sūri. It is also the first text on the astrolabe in Sanskrit. After Mahendra Sūri, Padmanābha, Cakradhara, Gaṇeśa-Daivajña etc. composed Sanskrit texts on instruments, but most of them remain unpublished.

YANTRA-KIRAṆĀVALĪ OF PADMANĀBHA

Padmanābha composed the *Yantra-kiraṇāvalī* or *Yantra-ratnāvalī* (ca.AD 1400), of which Chapter II entitled *Dhruvabhramaṇa-adhikāra* is well known[1].

The *dhruvabhramaṇa-yantra* is a rectangular board with a slit to observe the "polar fish" (a group of stars around the North Pole) for finding time.

The Tagore Library of Lucknow University has a unique manuscript of its Chapter I, namely the *Yantrarāja-adhikāra*.[2] It consists of 116 verses and has a commentary, probably written by its author Padmanābha himself[3]. It describes the construction and use of an astrolabe. Padmanābha takes the circumference of the instrument as the diurnal circle of the first point of Cancer, and draws the diurnal circles of the first points of Aries and Capricorn inside. It is opposite to the usual way. He writes:

"A circular instrument, which is made of metal, constructed with any arbitrary radius by means of a pair of compasses (*karkaṭa*, it also means Cancer), whose circumference is supported loosely, should be made. Then a horizontal and a vertical straight lines, passing through the centre, should be drawn. The upper half of the circumference should be graduated with degrees of three signs (90^0) on both sides. Two (horizontal) lines should be drawn on one-third-less forty one degrees($40^0 40'$) and twenty five and a twelfth degrees ($25^0 5'$) (above the horizontal line passing through the centre)."[4]

"A pair of diurnal circles which are touching them (two horizontal lines) should be drawn. The intermediate space, between the diurnal circle of Capricorn and Aries, and also (between the circles of Aries and) the circumference, should be divided by degrees of obliquity of the ecliptic along the vertical line. Then the intermediate space between the centre and the circle of Capricorn which is the lowest circle should be divided into sixty six degrees. The sun indeed rotates along a certain circle which is called Cancer etc."[5]

The above mentioned values $40^{0}40'$ and $25^{0}5'$ show that the obliquity of the ecliptic[6] was taken as about $23^{0}50'$, although the value of the co-obliquity of the ecliptic is given as 66^{0} in the next verse, and calculation is made by taking the obliquity of the ecliptic as 24^{0} which is the common value in Hindu astronomy. The value $\varepsilon = 23^{0}50'$ does not appear in the earlier Hindu works, but it is close to the Ptolemy's value[7], $\varepsilon=23^{0}51'20''$. On the contrary, Mahendra Sūri[8] used $\varepsilon=23^{0}35'$ which is the same as al-Battānī's value[9]. It seems that the measure of the instrument has been borrowed from certain Islamic source, which is different from the source of Mahendra Sūri, but the theory of the instrument is explained in Hindu traditional manner.

The author Padmanābha further continues to explain the method to draw the six o'clock line, prime vertical, altitude circles etc. quoting Śrīdhara, Brahmagupta and Bhāskara II in his commentary.

He wrote that six instruments were described[10], but only two *adhikāras*, which describe one instrument each, are now available.

DIKSĀDHANA-YANTRA OF PADMANĀBHA

The Oriental Institute of Baroda has a unique manuscript of the *Diksādhana-yantra* written by Padmanābha[11]. It consists of 18 verses. D.Pingree conjectured that it is Chapter I of the *Yantra-kiraṇāvalī* or *Yantra-ratnāvalī*[12], but it is wrong because the colophon of the *Yantrarāja-adhikāra* of the Tagore Library (Lucknow University) clearly states that it is Chapter I of the *Yantra-kiraṇāvalī*, hence the *Diksādhana-yantra* cannot be Chapter I of the *Yantra-kiraṇāvalī*. The manuscript of the *Diksādhana-yantra* does not mention the title *Yantra-kiraṇāvalī* nor the *Yantra-ratnāvalī*.

The *diksādhana-yantra* is a wooden horizontal square board with a vertical 12 *aṅgula* gnomon at its centre. A circle of radius 20 *aṅgulas* is drawn at its centre, and concenteric circles are drawn inside at every *aṅgula*. Then east-west and north-south lines, passing through the centre, are drawn. He gives the *agra* (radius of the circle into sine of amplitude) corresponding to the radius which is equal to the desired hypotenuse (the hypotenuse of a triangle whose base is the desired shadow and upright is the 12 *aṅgula* gnomon) as follows:[13]

$$Agr\bar{a} = \frac{R\sin\delta \times palakarṇa \times iṣṭakarṇa}{R \times 12}$$

where R is the radius of the celestial sphere, δ is the declination of the sun, *palakarṇa* is the equinoctial midday hypotenuse (i.e. $(12/\cos\phi$, where ϕ is the terrestrial latitude), and *iṣṭakarṇa* is the desired hypotenuse. This *agrā* means the difference between the length of the equinoctial midday shadow and the north-south projection (*bhuja* or base) of the desired shadow. He instructs to obtain east-west projection (*koṭi* or upright) of the shadow from the *bhuja* applying the Pythagorean theorem. He requires to find time using *bhuja*, but the method is not explicitly given. He also asks to draw the locus of the tip of the shadow. The locus is considered to be a circle which passes through the tip of the midday shadow and the tips of the shadows whose corresponding hypotenuse is 60 *aṅgulas* in the morning and evening. He writes:

"The north-south projection (*bāhu* or *bhuja*) of the shadow and the east-west projection (*koṭi*) of the shadow which are stated before should be determined from the 60 *aṅgula* hypotenuse of shadow. The north-south projection should be diminished by the midday shadow. It is the arrow (versed sine). The *koṭi* is the desired sine. Determine the measure of the circle with the help of them and midday shadow. If the circle is drawn with that diameter, then the tip of the shadow of the desired gnomon will not leave its circumference on that day"[14].

PRATODYA-YANTRA OF GAṆEŚA-DAIVAJÑA

Gaṇeśa Daivajña (b. AD 1507) wrote the *Pratoda-yantra*[15], which consists of 13 verses. It is a kind of sun-dial with a horizontal gnomon.

Munīsvara (b. AD 1603) described this instrument in his *Siddhānta-sārvabhauma*[16] in 8 verses[17]. It has a commentary by Munīsvara himself. The extract of this Munīsvara's version was frequently copied. Munīsvara calls it *pratoda-yantra* in the text[18], but calls it *cābuka-yantra* in the commentrary. Hence the extract is sometimes entitled *Cābuka-yantra*[19] and sometimes *Pratoda-yantra*[20]. In the case of the latter, the name of the instrument in the comentary was changed into *pratoda-yantra*. The Munīsvara's version has been published[21]. Sometimes this Munīsvara's version is wrongly stated as *Gaṇeśa's* work. D.Pingree mentions a *ṭīkā* by *Gaṇeśa* himself on the *Pratoda-yantra*[22], but its existence is doubtful[23].

CONCLUSION

The history of astronomical instruments in India between Bhāskara II and Jai Singh Sawai is still unclear although there are several sources. The present paper is only a preliminary report of this subject on which I am now doing research.

ACKNOWLEDGEMENTS

I am thankful to Dr. K. S. Shukla, Retired Professor in Mathematics, Lucknow University, who is guiding my research.

I am also grateful to the Directors and/or Librarians of the following Libraries who kindly allowed me to consult manuscripts (The abbreviations used in the notes are indicated within brackets).

1 Tagore Library, Lucknow University, Lucknow(Lucknow).
2 Sarasvati Bhavan, Sampurnanand Sanskrit Vishvavidyalaya, Varanasi (Benares).
3 Vishveshvaranand Vishva Bandhu Institute of Sanskrit and Indological Studies, Panjab University, Hoshiarpur (VVRI).
4 Scindia Oriental Research Instiute, Vikram University, Ujjain (SOI).
5 Oriental Institute, Baroda (Baroda).
6 The Asiatic Society of Bombay, Bombay (AS Bombay).

REFERENCES AND NOTES

1 Dikshit,S.B. (1981). Bharatiya Jyotish Shastra, Part II. English tr. by R.V. Vaidya, p.231. India Meteorological Department. Garrett,A.ff.(1902). The Jaipur Observatory and its Builder, pp.62-63. Allahabad. I am grateful to the Librarian of BHU who supplied me its photocopy. There are several manuscripts of this adhikāra. See Pingree,D. (1981). Census of the Exact Sciences in Sanskrit, Ser.A, vol.4, pp.170-172. Philadelphia: American Philosophical Society. (hereafter Census). I have used VVRI 2481 and 469; AS Bombay 2451 (BD 298); and Baroda 9588 and 3168. In VVRI 2481, the name of the author is wrongly indicated as Gaṇeśa-Daivajña.

2 Lucknow 45888, 33 ff,copied in Saṁvat 1634 Mārgaśīrṣa-month śukla-pakṣa 8th tithi Monday (= AD 1577). Its colophon clearly states that it is Chapter I of the Yantra-kiraṇavalī. (Śrīpadmanābhaviracitāyāṁ yantrakiraṇāvalyāṁ yantrarājādhikāro vāsanābhāṣyasahitaḥ prathamaḥ).

3 Although the name of the commentator is not given in its colophon, there is a cancelled colophon in the folio 21b, which states that commented by himself (svavivṛtti).

4 Verse No.3. (Folio 3a).

5 Verse No.4. (Folio 3a-3b).

6 As was shown by Padmanābha in the verse No.6 (Folio 7b), the radii of the diurnal circles of Aries and Capricorn are:

$$a = \frac{r \times R \sin(90^0 - \varepsilon)}{R + R\sin\varepsilon}, \qquad b = \frac{r \times R\text{versed} \sin(90^0 - \varepsilon)}{R + R\sin\varepsilon}$$

where r is the radius of the instrument, a and b are the radii of the circles of Aries and Capricorn respectively, ε is the obliquity of the ecliptic. Therefore, the following equations give the value of ε which gives the values mentioned in the verse No.3.

$$40^{0}\ 40' = \sin^{-1} \frac{\cos \varepsilon}{1 + \sin \varepsilon} \quad \text{, and}$$

$$25^{0}\ 5' = \sin^{-1} \frac{1 - \sin \varepsilon}{1 + \sin \varepsilon}$$

The former gives $\varepsilon = 23^{0}49'8''$ and the latter gives $\varepsilon = 23^{0}\ 51'48''$.

7 Neugebauer, O. (1975). A History of Ancient Mathematical Astronomy, Part I. p.31. Berlin Heidelberg New York: Springer Verlag.

8 Dikshit, S.B. op.cit., p.231.

9 Kaye, G.R. (1918). The Astronomical Observatories of Jai Singh, p.136. Calcutta: Archaeological Survey of India.

10 Commentary on verse No.3.

11 Baroda 3160, 2 ff, copied in Saṁvat 1639 Mārga-month 15th tithi Thursday (= AD 1582).

12 Pingree, D. Census, A-4, p.170 and also Pingree, D.(1981) Jyotiḥśāstra, A History of Indian Literature VI-4. p.53 Wiesbaden: Otto Harrassowitz.

13 Verse No.4.

14 Verse No.12 & 13.

15 I have used Benares 35702 and AS Bombay 245 IV (BD 298). Benares 35702 contains Munīsvara's version also.

16 Although its Pūrvārdha has been published in 3 volumes from Sampurnanand Sanskrit Vishvavidyalaya, Varanasi, its Uttarārdha which contains Yantra-adhiyāya is yet unpublished. I have used Benares 36922 and SOI 9421 (these two are text only), Baroda 9429 and AS Bombay 288 (BD 62) (these two have auto-commentary).

17 Verse Nos.63-70.

18 Verse No.63.

19 I have seen Benares 34999.

20 I have seen Benares 36676, 35630, 34353 and 35074; Baroda 3190; SOI 9414 and VVRI 4731.

21 Sharma, S.D. (1982). Pratoda Yantra. (Ed. and com. by Shakti Dhara Sharma), P.O.Kurali(Ropar) Pb. (INDIA): Martand Bhavan. I am grateful to Dr. S.D.Sharma, Dept. of Physics, Punjabi University, Patiala, who kindly gave me a copy of his book.

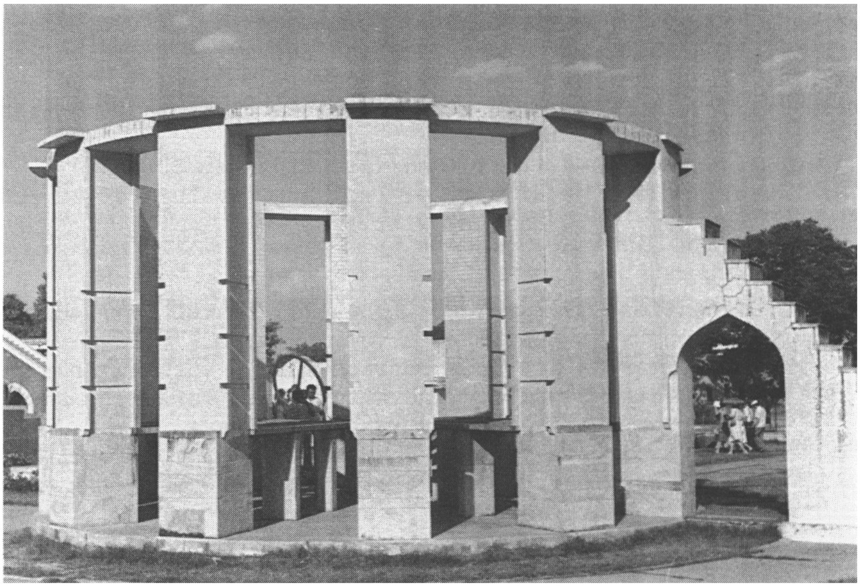
22 Pingree, D.(1971) Census, A-2, p.106. Philadelphia.

23 Among 10 manuscripts which Pingree mentions, I have confirmed that the following manuscripts are Munīsvara's version. Benares 36676, 35630 and 34353; Baroda 3190; and VVRI 4731.

DISCUSSION

S.M.R. Ansari : In what other instruments do you find Arabic Islamic instruments ?
Have you found any other Sanskrit source in which Arabic-Islamic influence appears ?
For which latitude the plates of Astrolabe constructed ?

Y. Ohashi : I have not found other instruments of Padmanābha. I cannot say definitely at this moment, but I suppose that there are some other Sanskrit sources which describe Islamic instruments. Since this text is still under study, I would like to present those details on another occasion.



Ram Yantra. A cylinder structure, 5 m high and 7 m in diameter for measuring the azimuth and zenith angles.