Indian Journal of History of Science, 52.2 (2017) 228-230 DOI: 10.16943/ijhs/2017/v52i2/49062

B S Shylaja and V S S Sastry : *Jantar Mantar Observatories of Jai Singh*, Bangalore Association for Science Education, Jawaharlal Nehru Planetarium, Bengaluru-560001, pages 20; price Rs. 500/- US $ 49/-

S Balachandra Rao*

This is a unique book which brings virtually direct experience of the masonry astronomical instruments of *Jantar Mantar* built by the illustrious Raja Sawai Jai Singh (1688-1743). While there are a couple of famous works on Raja Swai Jai Singh's astronomical observatories, the uniqueness of the present book lies in including the 3-D "pop-up" illustrations of the astronomical masonry instruments of *Jantar Mantars* at Jaipur (Rajasthan) and Delhi.

Sawai Jai Singh-II, a highly trusted *sāmanta*(feudatory) of the Mughal emperor Mohammed Shah was the ruler of the Rajput state of Amber. Besides being an effective ruler, Jai Singh was a proficient astronomer and encouraged the pursuit of astronomy by inviting specialists in the field from Europe, Central Asia and India. He commissioned compilations of astronomical tables in Persian (*Zīj-e-Muhammad Shahi, ZEM*), *Dṛk-pakṣa-sāriṇi* (Sanskrit) etc.

He initiated constructions of five stone observatories – comprising huge instruments – in Delhi (1710), Ujjain (1729), Varanasi (1719), Jaipur (1719) and Mathura of which the last one is now extinct. The other four are still operational. The popped-up models give an immediate understanding of the form and function of each instrument. The very first such model Sāmrāṭ *Yantra* is a large sun-dial, comprising mainly a central gnomon (*śanku*) i.e. a vertical pole and a calibrated scale. As the shadow of the gnomon moves crossing the scale, the time during daytime can be reckoned.

Dakṣiṇottara Bhitti, an instrument to mark the noon meridian passage of the Sun is a graduated semi-circle on the north-south wall. The pin at the centre casts its shadow on the graduated scale at the actual noon (meridian passage). The reading on the scale measures the maximum altitude (*unnati*). This in turn gives the sun's declination (*krānti*); the north-south co-ordinate. The north-south shift of the Sun enables one to fix the extreme north and south points, reached by the Sun, heralding the *dakṣināyana* (southern course) and the *uttarāyana* (northern course). These correspond respectively to the summer and winter solstices, taking place around June 22 and December 22 currently. This simple instrument was used to measure the obliquity of the ecliptic (with the celestial equator) also. The authors point out that in 1729 CE, it was measured to be $23^{o}\ 28'$ and that Hipparchus gave its value as $23^{o}\ 51'$ for his time (2nd century BCE). The instrument at Ujjain is the biggest (radius 6.17 metres) as compared to those at Jaipur, Varanasi and Delhi.

The *Ṣaṣṭāmśa Yantra* in Delhi enables determination of the north-south motion of the Sun. It is a small chamber in the eastern side with a pin-hole in the ceiling. The floor has a circular arc with a pin-hole in the ceiling. The floor has a

*Hon.Director, Bhavan's Gandhi Centre of Science and Human Values, #43/1, Race Course Road, Bengaluu-560001, Email: balachandra1944@gmail.com

circular arc with calibrated sixty degrees of angle. The Sun reaches the extreme north and south points respectively at the summer and winter solstices, around June 22 and December 22. The image of the pin-hole moves along the graduated arc at noon. This device fixes the solstices, useful in the preparation of calendar based on actual observations.

Nāḍi Valaya is a device to mark the passage of the Sun across the celestial equator (*viṣuvat vṛtta*). It is well known that the durations of the day and night are equal on the two equinoctial days around March 21 and September 23. The points of the Sun on the ecliptic (*krānti vṛtta*) on these two days are referred to as vernal equinox (*vasanta viṣuva*) and autumnal equinox (*śarat viṣuva*) respectively. These are the points where the ecliptic cuts the celestial equator.

Cakra Yantra is a circular ring mounted on an axis parallel to the axis of the earth's rotation. Another rod is placed perpendicular to the axis of rotation. The circle and the central rod are calibrated. A sighting tube is attached at the centre to align with a celestial body to be observed. The graduated marks on the instrument provide the north-south coordinates. The time (in hours) to reach the meridian is the other coordinate. This can be read out from a circular disc fixed at the base of the axis of rotation. The instrument is seen at Jaipur and Varanasi.

The other instruments of importance at the *Jantar Mantars* are (1) *Jaiprakāśa Yantra and Kapāla Yantra*, (2) *Unnatāmśa Yantra*, (3)*Miśra Yantra*, (4) *Krānti Vṛtta* (Ecliptic), (5) *Śaṅku Yantra* and (6) *Yantrarāja* (Astrolabe).

A small ring is pivoted at the centre of a hemispherical bowl which represents the sky. Its shadow inside the bowl reads out the altitude and azimuth. This information is passed on to another instrument called *Kapāla Yantra* to yield the celestial coordinates of the Sun.

Jaiprakāśa Yantra is a similar, but more sophisticated instrument. This comprises two complimentary bowls. There are six calibrated marble slabs in each of them. During the day the shadow of the central ring gives the altitude and azimuth. During the night, through a sighting tube the coordinates of any visible heavenly body can be obtained.

Unnatāmśa Yantra is a simple device for measuring the altitude (the angle above the horizon) of a heavenly body. For the altitude of stars and planets a sighting tube is also provided.

Miśra Yantra is a special instrument consisting of a gnomon (*śanku*) at the centre and four dials, with different orientations, above which the shadow of the gnomon can be read out. The eastern and western walls are graduated for a sundial – *Samrāt Yantra*. Its northern wall is purposely inclined – not vertical – so that the shadow of the gnomon (by the Sun) can be read on the dial called *Karkarāśi Valaya* only on the summer solstice day (June 22).

The four central dials put together is called *Niyat Cakra*. The different planes of these dials enable one to get the local times at places of four different longitudes. It is found that the two dials on the west correspond to the longitudes of Zurich and Greenwich while the two on the east correspond to Notkey in Japan and the island Serichew in Pacific Ocean. It is noted by the authors that the identifications are done only recently and not at the time of Jai Singh. The *Dakṣiṇottara* (south-north) *Bhitti*, explained earlier, is on the eastern wall while the *Karkarāśi Valaya* is on the northern wall.

Miśra Yantra also has an additional structure called *Agra Yantra* in the north-west. The authors point out that its function is not known. But they guess that it may be meant to read time specifically on the day of the winter solstice (December 22). A clear schematic diagram of this structure is provided in page 18 of the book.

Krānti Vṛtta (ecliptic) is a relatively new instrument installed in 1902 as a replacement for the original one. It is used to estimate the positions of the Moon and the planets with reference to the ecliptic, the apparent path of the Sun round the earth. It provides a scale inclined to the equator at 23° 27′ so that the coordinates measured along the equator are converted to the ecliptic ones, the celestial longitude and latitude. Two sighting tubes are also provided for viewing the heavenly bodies.

Śanku Yantra (gnomon) is a simple vertical stick mounted perpendicular to a graduated circle to read the Azimuth. The length of the shadow can be used to estimate the Altitude. This instrument is seen only in Ujjain.

Yantra Rāja (astrolabe) is an instrument used in the past by navigators to measure the local time, sidereal time, latitude and the time in the night. At *Jantar Mantar* there are two huge circular brass discs. The instrument has a plate which has the projections of stars onto a plate. The astrolabe has only the plate as a fixed dial and all the other parts namely Rule, Rete and Alidade – the calibrated scale, the star indicator and the sighting tube – are movable. In the case of the Sun the shadow alignment suffices to read out the altitude. The circle called 'Rete' has some bright stars marked. It can be moved on the dial to read out the azimuth corresponding to the altitude. The plate has equal azimuth and equal altitude circles drawn for a given latitude (of a place). During the day time the Sun's position can be adjusted with the help of the ecliptic scale. The scale called 'rule' can be moved to read the times of sunrise and sunset. The same can be done in the case of stars with the help of 'rete'. All these are clearly explained in a diagram for the astrolabe for Bengaluru (latitude =13′ N approximately).

On the whole this book is truly a boon for students as well as interested general readers. In the process of appreciating the instruments of *Jantar Mantar*, the reader learns practical observational astronomy. The advantage of the bilingual presentation is that the Kannaḍa knowing readers will understand the astronomical concepts and the functioning of the instruments (through 'pop-up' images) better. Further, the readers become familiar with Indian equivalents, of technical terms in astronomy like *krānti* (declination), *śara* or *vikṣepa* (latitude of a heavenly body), *krānti vṛtta* (ecliptic), *viṣuvat vṛtta* (celestial equator), *khamadhya* (zenith) etc.

For using the pop-up part of the book the following link is very helpful: https://www.youtube.com/watch?v=szQmuRbaP7Y