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INSTRUMENTS IN SŪRYASIDDHĀNTA

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Abstract: Indian has a long tradition of observational astronomy. In this paper, I am going to discuss several astronomical instruments; their names and descriptions given in Sūryasiddhānta.

Keywords: Gnomon, Clepsydra, Yaṣṭi Yantra, Gola-Yantra, Cakra Yantra, Nara Yantra, Mayūra Yantra, Vānara Yantra, Sūtrareṇugarva Yantra, Kapāla Yantra.

Introduction

Astronomy is an observational science. The position and movements of heavenly bodies have to be observed and recorded very accurately before a theory to explain their motions can be propounded. All theories have to be revised if their predictions are not in accordance with observational results. Also, for many reasons, the time since sun-rise has to be measured precisely. For example, some ritual perpose accurate time is necessary. However, visual observations are not very accurate and it is necessary to devise instruments to ascertain the positions and motions of heavenly bodies and measure the duration of time. [5] Thus, instruments are played an important role in observational science specially in astronomical observations. In ancient time there were no instruments to observe, unless the naked-eyed is used. The earliest written records of astronomical knowledge in India are found in Vedic literature. But there is no record of astronomical instruments in Vedic literature proper and only naked eye observations must have been made in this period.

In Vedāṅga literature and some other post Vedic literature mentioned some astronomical instruments. It comes to our knowledge that two earliest astronomical instruments are the Gnomon and the Clepsydra. The staff or yaṣṭiyantra is the other earliest instrument. The records of shadow-length of the gnomon or the staff instrument are used for measuring time. The gnomon was used for the determination of cardinal dirctions. Its method was first described in the Kātyāyana-Śulbasūtra(I.2). [4]

The basic development of astronomical instruments began from the post Vedic period. But the real progress of the usage of Indian astronomical instruments began from the Siddhāntic period. Major classical Siddhāntas are helped to know the development of astronomical instruments in Indian astronomy. In Siddhāntic texts of Siddhāntic period we see the names of many instruments, their description and functions. It comes to our notice that a separate chapter on astronomical instruments can be found in many astronomical Siddhāntas. In this paper we are going to discuss the astronomical instruments in Sūryasiddhānta.

Sūryasiddhānta

Sūryasiddhānta, a standard Indian astronomical treatise widely accepted in India. It was one of the earliest Indian scientific astronomical works, which began to take shape from about the fourth or the fifth century CE at a time when old astronomical ideas and calculations came to be revised and placed on a scientific and mathematical basis. The text in its present form is of much later development specially many corrections and interpolations were introduced. There is a considerable agreement between the Sūryasiddhānta as described by Indian astronomer Varāhamihira in his Pañcasiddhantikā with the modern Sūryasiddhānta. But, as Indian scholar Probodh Chandra Sen Gupta has shown, Varāhamihira himself amended the old version in accordance with the teachings of Āryabhaṭa I (see: Āryabhaṭa's lost works', Bulletin of the Calcutta Mathematical Society, vol.22, 1930; Introduction to E. Burgess' Sūryasiddhānta, Calcutta University, 1935). Modern Sūryasiddhānta has fourteen chapters and containing five hundred verses. These fourteen chapters are-

i. Madhyamādhikāra. (On mean motions of the planets). Number of verses-70.
ii. Spaṣṭādhikāra.(On true places of the planets). Number of verses-69.
iii. Tripraśnādhikāra.(On the three enquires relating to direction places and time). Number of verses-50.
iv. Candragrahanādhikāra. (On eclipses with special reference to the lunar eclipses). Number of verses-26.
v. Sūryagahanādhikāra. (On solar eclipses, it actually deals with parallax in solar eclipses). Number of verses-17.
vi. Chedyakādhikāra. (On the projection of eclipses). Number of verses-24.
In S.N. Sen's book the 6th chapter named as chedyakādhikāra but Śri Vijñānānanda Swamī mentioned it as Parilekhādhikāra.
vii. Grahayutyadhikāra. (On planetary conjunctions). Number of verses -24.
viii. Nakṣatragrahayutyadhikāra. (On the asterisms). Number of verses -21.

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ix. Udayāstādhikāra. (On heliacal rising and settings). Number of verses-18
x. Śṛñgonnatyadhikāra. (On the moon's rising and setting and on the elevation of the moon's cusps). Number of verses -13.
xi. Pātādhikāra. (On the pātas or faults, i.e., the malignant aspects of the sun and the moon, mainly of astrological import). Number of verses -22.
xii. Bhūgolādhyāya. (On cosmology, geography and dimensions of the creation).
Number of verses- 90.
xiii. Jyotiṣopaniṣadādhya. (On instructions on astronomical instruments, armillary spheres etc). Number of verses-25 (5) and
xiv. Mānādhyāya.(On reckoning time). Number of verses -27.

Commentators of Sūryasiddhānta

Numerous writers wrote commentary on Sūryasiddhānta.
Some of the eminent commentators' are-

Allanāyasūri, Amreḍya, Āryabhaṭa, Bhūdharasūri, Caṇḍeśvarācārya, Cola, Dādābhāi, Kāma, Kamalākara, Kṛṣṇa Daivajña, Kumāratanayayogin, Madanapāla, Mādhavācārya, Mallikārjuna, Nṛsiṃha, Parameśvara, Raṅganātha, Śrikaṇṭha, Tammaya, Viśvanātha Daivajña and Yallaya.

Anonymous commentaries of Sūryasiddhānta

We find a remarkable number of anonymous commentators of Sūryasiddhānta which is given below-

Sūryasiddhāntabhāsya, Sūryasiddhānta-jyotiṣa, Sūryasiddhānta-Sāraṇi, Sūryasiddhāntasubodhinī,Sūryasiddhāntatīkā, Sūryasiddhāntaṭippanī, Sūryasiddhāntodāhraṇa etc.[6]

Now we are going to describe the different astronomical instruments as found in the Sūryasiddhānta.

1. Gola-yantra (armillary sphere)

Indian astronomers devised the instrument armillary sphere i.e. 'Gola-yantra' which was first described in Āryabhaṭīya of Āryabhaṭa I. He narrated as follows-

"kāṣṭamayaṃ samavṛttaṃ samantataḥ samaguruṃ laghuṃ golaṃ ।
pārada tailajalaistaṃ bhramayet svadhiyā ca kālasamam ॥"22॥

It is to be noted that in the second stanza of this verse instead of pārada some medieval Indian mathematicians like Nīlakaṇṭha, Parameśvara, Someśvara and others wrote it Pārata. [7]

"The sphere (Gola-yantra) which is made of wood, perfectly spherical, uniformly dense all round but light (in weight) should be made to rotate keeping pace with time with the help of mercury, oil and water by the application of one's own intelligence." Āryabhaṭīya (vol.-IV. 22).

Subsequently Varāhamihira, Brahmagupta, Lalla, Śripati and Bhāskara II wrote on armillary spheres (Gola-yantra). In most cases Gola-yantra was discussed in Goladhya chapter. A few medieval Indian authors called this chapter or subchapter as Golabandha.

The existence of armillary sphere can be found in Greece since the time of Hipparchus but armillary sphere originally developed in India. This was opined by Colebrook considering the major and fundamental differences between the devices in India and those described by Ptolemy.

The armillary sphere which is given in the 18th verse of a solid globe of wooden representing the earth, in the midst of this instrument, is of itself enough to render impracticable its application to purposes of astronomical observations. But this was rectified by A.K. Chakraborty in his observations Sūryasiddhānta

Such impracticable directions, however, cannot but inspire the supposition that the instrument may never have been constructed except upon paper.

Let us describe the construction of the globe of the stellar sphere with another wooden globe fixed inside it at the centre to represent the earth. Then insert a staff through the common centre of the two globes protruding through each end in the direction of the two Merus. Fix two supporting ring or hoops to the ends of the protruding axial staff.

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Gola-yantra is mentioned in verses-3 and 4, chapter-xiii of Sūryasiddhānta which is as follows-

"Bhūbhagolasya racanāṁ kuryādāścarya kārinīm ।
Abhṣṭam pṛthivīgolaṁ kārayitvā tu dāravm." ॥ 3. ॥
"Daṇḍaṁ tanmadhyagaṁ merorubhaayatra vinirgatam ।
Ādhārakaksādvitayaṁ kakṣā vaiṣuvatī tathā." ॥ 4. ॥ [1]

The English meaning of the above verses-

Prepare the wonder- working fabric of the terrestrial and stellar sphere (bh ūbhagola). Having fashioned an earth-globe of wood, of the desired size. ॥3॥.

Fix a staff, passing through the midst of it and protruding at either side, for Meru; and likewise, a couple of sustaining hoops (kakṣa), or the equinoctial hoop. ॥4 ॥.[2]

2. Śaṅku, Gnomon (The Sun-dial)

The sun-dial is an astronomical instrument described in verses 1 and 2 of chapter- xiii of Sūryasiddhānta. It is an important and well-known instrument to observe heavenly bodies in India. Although we call it a sundial but it does not contain any scale for measuring hour angle of the sun or not used for that purpose. The sun-dial which is known to us is generally known as Śaṅku (Gnomon) in Sanskrit literature i.e., in the medieval Indian astronomy. This term "Śaṅku" can be found in Sūryasiddhānta.

On a horizontal surface made of a stone slave or cement (vajralepa) perfectly leveled by water, draw a circle of any suitable radius. On the centre of this circle fix gnomon vertically. The length of this gnomon will always be reckoned as aṅgulas. Śaṅku is mentioned in verses- 1 and 2, chapter- iii of Sūryasiddhānta which is as follows-

"Śilātale'mbusṁśuddhe vajralepe'pi va same. ।
Tatra Śaṅkvaṅgulairiṣṭiḥ samaṁ maṇḍalamālikhet" ॥ 1 ॥
"Tanmadhye sthāpayecchaṅkuṃ kalpañddvādaśāṅgulan. ।
Tacchāyāgraṁ spṛśedyatra vṛtte pūrvāparārardhayoḥ." ॥2 ॥

The English meaning of the above verses-

On a stony surface, made water level, or upon hard plaster, made level, there draw an even circle, of radius equal to any required number of the digits (aṅgulas) of the gnomon (Śaṅku). Verse-1.

And its centre, set up the gnomon, of twelve digits of the measure fixed upon: and where the extremity of its shadow touches the circle in the former and after part of the day. (Verse-2) [Ref.1. p.158]

3. Yaṣṭhi – yntra (staff instrument)

The modern Sūryasiddhānta has mentioned the name of the instrument yaṣṭhi yantra (staff instrument), which is use for measuring.

Yaṣṭhi yantra consists of horizontal slab of stone perfectly leveled by testing with water. On it a circle is described with radius equal to the tabular radius, a small depressing is made at the centre. Through the centre the east-west and north-south line are drawn.

4. Cakra Yantra (The wheel Instrument)

Cakra yantra is an astronomical instrument, which described in Sūryasiddhānta. It is used for measured time. The cakra yantra consists of a circular wheel with a projected peg at the centre held vertically. The lost point of the wheel and also the end of a horizontal diameter are specially marked on the wheel. To use it, its edge is tuned to works the sun. The shadow of the peg falls on the graduated rim of the wheel. The reading on this scale gives the altitude and zenith distance of the sun and from these the time at the instant is found.

Cakra yantra is mentioned in verse-20, chapter-XIII of Sūryasiddhānta which is as follows-

"Ekākī yojayedbījaṁ yantre vismayakāriṇi ।
Śaṅkuyaṣṭhidhanuścakraiśchāyāyantrairanekathā." ॥ 20 ॥

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It is English translation which is as follows-

When quite alone, are should apply quicksilver to the wonder- causing instrument. By the gnomon (śaṅku), staff (yaṣṭhi), arc (dhanu), wheel (cakra), instruments for taking the shadow, of various kinds.

5. Nara Yantra (Mon instrument)

This instrument is a gnomon of standard height of a man. On chapter-xiii verse-24 described that a man instrument can be used in day time when the sun is clear. Nara yantra, mentioned in verse- 24 of chapter – xiii of Sūryasiddhānta which is as follows-

"narayantraṁ tathā sadhu divāvca vimaleravau ।
Chāya saṁsāhanaiḥ proktaṁ kālasādhana muttamam." ॥ 24 ॥

It is English translation which is as follows-

So also, the man-instrument (narayantra) is good in the day-time, and when the sun is clear. The best determination of time by means of determination of the shadow has been explained.

6. Mayūra and Vānara yantra (Peacock and monkey instrument)

Mayūra and Vānara yantra is an astronomical instrument. It is mentioned in verse-21, chapter- xiii of Sūrya- Siddhānta which is as follows-

Added diacritic matks to above English translation-

"gurūpadeśādvijñeyaṁ kālajñamatndritaiḥ ।
Sa sūtrareṇugarbhaiśca samyakkalaṁ prasādhayet." ॥ 21॥

The English meaning of the above verse-

According to the instruction of the preceptor (guru), is to be gained knowledge of time by the diligent. By water-instrument, the vessel (Kapāla), etc., by the peacock, man, monkey and by stringed sand-receptacles, one may determine time accurately.
It is used for measured time.

7. Sūtrareṇugarva yantra (Stringed sand instrument)

It is an astronomical instrument. This instrument consists of a vessel suspended by strings filled with dry sand with a whole made at the bottom of the vessel as n outlet of the sand inside. The time is perhaps measured by the rate of flow of the sand or the interval in which the vessel is emptied, the text has not specified it.

8. Kapāla yantra (The water instrument)

The Kapāla yantra described by Vrāhmihira and others is very different from Kapāla yantra described by Ārybhaṭa and Sūryasiddhānta, the letter being actually water instruments. This instrument is a hemisphere with a gnomon in the centre. The length of the gnomon is equal to the radius of the hemisphere so that the upper tip of the gnomon is at the centre of the hemisphere. It is placed on the even ground and saised so that the elevation is equal to the latitude of the place and plane of its rim coincides with the plane derermined by the east-west line and the direction of the north pole. Thus, the gnomon points towards the point of intersection of the meridian circle and the celestial equator. The instrument may be made of metal or of good wood. At the centre of the hemisphere also east-west and north-south points of the nm.

On the rim the signs of the zodiac are marked in the reverse order. At the time of sun-rise the instrument is rotated so that the shadow of the gnomon falls on the sign in which the sun is. As the sun rises the shadaw of the gnomon point moves downwards from which the angular heigh of the sun may be obtained. And thus, the time since sun-rise can be calculated as well as the sign which is at the horizon at that instant may be obtained.

Kapāla yantra is mentioned in verse-23, chapter-XII of Sūryasiddhānta which is as follows-

"Tāmrapātra madhaś chidraṁ nyastaṁ kuṇḍe'malāmbhasi ।
Ṣaṣṭirmajjatyahorātre sphuṭaṁ yantraṁ kapālakam" ॥ 23 ॥

It is English translation which is as follows- A copper vessel with a hole in the bottom, set in a basin of clean water, sinks sixty times in a day and night, and is an accurate hemispherical instrument.

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Conclusion

In various astronomical texts in ancient India, it comes to our notice that the names of various instruments in the same or different names as describe in Sūryasiddhānta. Āryabhaṭīya of Āryabhaṭa I described several interesting astronomical instruments. This work is now lost but the description of the instruments survives in Rāmakṛṣṇa Ārādhya's commentary on the Sūryasiddhānta. In the fourteenth chapter of Pañcasiddhāntikā, Varāhamihira discussed some instruments. Brahmagupta in his Brahmasphuṭa-siddhānta described the construction and use of instruments like armillary sphere (Gola-yantra), Śaṅku yantra, Ghaṭikā yantra, Kapāla yantra, Yaṣṭhi yantra, Cakra yantra etc.

Rāmacandra Vajpeyn in his yantra-prakāśa in 1428 described the importance of instruments in astronomy. Which is as follows:

"Tanur netrair nyūnā nṛpatirahitā rājanagarī
Srasyo niṣpadmā yuvatir api kāntena rahitā
Niśā niḥśūāṃśuḥ sard api yathā cakrarahitā
Tathā jyotirvidyā bhavati viphalā yantrarahitā. ॥"

English translation runs as follows:

Like body without eyes, royal capital minus the king, lakes devoid of lotus flowers, a young woman without a lover, the night without the moon, a river bereft of Cakravāka birds, even so astronomical science is fruitless without instruments.

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