



A study of ancient astronomical instruments and their relevance to modern time

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Abstract

This paper gives a brief account of ancient and modern astronomical Instruments with development of astronomical Science in India. Some of the measuring Instruments made up of simple mechanisms used for measurement of length, angle and time have been described in ancient literature however these instrument have unseen due to language constraints. These instruments were put into use by various ancient Indian astronomers and mathematician. Braham Gupta described ten types of instrument which were adopted by all subsequent writers with modifications. The Investigation of the recorded ancients astronomical instrument not only give us a glance of their historical developments but also provide overall concepts and knowledge about the mechanical characteristics for some referred function and application.

Keywords: sanku chaya, yasti, fish-figure, mngola, chakra, pitha and astralabe

1. Introduction

Arayabhata I (b.476 A.D.) occupies a prestigious position in the history of Indian astronomy and mathematics. In view of his important contributions, particularly to astronomy, he has been rightly regarded as the founder of scientific astronomy in India. His work namely, the Aryabhata Siddhanta which is available in its original form (see.)^[11]. Illustrious names in Indian astronomy following are Laladeva (c. 505 A.D.), Varahamihira (b. 505 A.D.), Bhaskara I (b.574 A.D.), Brahmagupta (b.598 A.D.), Lalla (b. 720 A.D.), Munjala (c.932 A.D.), Bhaskaracarya II (b.1114 A.D.). And Ganesa Daivajana (b.1507 A.D.) etc (see.)^[3, 6, 7, 11].

Astronomy is the oldest scientific discipline humankind has known. Being an ancient culture, India has a long tradition of astronomical and related activities. At present we have no definite clues to the astronomical knowledge of the Harappan people. The oldest Indian text exclusively devoted to the subject is the Vedanga Jyotisa which is generally dated about 1400 B.C. This work, mostly attributed to Lagadha, describes a rather inexact calendar in which a five year yuga is equated with 1830 civil days (see.)^[2].

Modern astronomy came to India into with the Europeans who needed it as a navigational and geographical aid. Building an astronomical observatory in the 18th century was one of the first scientific acts of the British in India. Astronomy in India has come a long way since independence, a number of astronomical centers have come up that seek to observe the universe in various wavelength bands, from ground and from space.

2. Ancient astronomical instruments

The only instrument of practical utility for astronomical purposed described in ancient Hindu works are the sundial and clepsydra. An Armillary sphere is also described as an instrument for purposes of demonstration. The brief explanations are mentioned (see.)^[3, 9, 11] below.

2.1 The Clepsydra (The water clock)

The Use of water clock is referred to in the Vedanga-Jyotisa. The more ancient or of water clock appears to have been simply a vessel with a small orifice at the bottom, through which the water flowed in a fixed unit of time, says a nadika (1 nadika = 24 minutes). According to the Surya- Siddhanta: A hemi- spherical copper vessel with a hole in the bottom, set in a vessel of pure water, sinking sixty times in a day and night. (See.)^[8, 9, 12].

2.2 The Gnomon

It is mentioned in the Atharveda. It is vertical rod (gnomon) with 12 divisions first description as well as Varahamihira in his Panchasiddhantika gives details of its use in astronomy. The Panchsiddhantika instruction are: Mark from the centre three times the end of the gnomon's shadow and then describe two fish figures (The fish figure is the common part of two intersecting circle). There upon describe a circle, taking for radius a string that is fastened to the point in which the two strings issuing from the heads of the fish figures intersect, and that is also long as to reach the three points marked. On the given day the shadow of the gnomon moves in that circle, and the base of the gnomon is the south-north line; and the interval in the north direction, is the midday shadow (see.)^[4, 9, 10].

2.3 Gola Yantra (Armillary sphere)

The first mention of Golaynatra is on the Aryabhatiya (Golapada) composed by Aryabhata in 499 A.D, according to Aryabhata (see.)^[1, 4, 10].

काष्टमयं समवृत्तं समन्ततत्सम् गुरु लघुं गोलम् ।

पारत तैलजैलस्तं भ्रमयेत्स्वधिया च कालसमम् ।।

Which means

The Golanatra was a uniformly round circle made of wood (bamboo) and which was of uniform weight (density). It was

leveled with water (Oil or mercury). A Salaka (rod) was fixed in it in the south-north direction.

This is really a wooden model of the celestial sphere showing the various great circles used in astronomy. The golyantra, was used mainly for purpose of demonstration. The outer sphere is called khagola, which has a polar axis. The sphere consists of a number of great of circles to represent the horizon, the meridian, the equinoctial, The prime vertical, the 60° clock circle and soon. Inside the Khagola is fixed another sphere, the bugola on which are presented the ecliptic, the lunar and planetary orbits called the Ksepa-vrttas, the declination and the diurnal Circle. This can be made to revolve round a polar axis. In same manner, there is a third sphere, the drggola, which is supported on the axis of the khagola produced. The whole arrangement of the golyantra is such that khagola and drggola remain fixed while the innermost bhugola alone can be made to revolve. (see.)^[4, 12].

3. Brahmagupta's astronomical instruments

According to *Brahmagupta's* Brahmasphuta-Siddhanta (See.)^[9].

सप्तदश कालयन्त्राण्यतो धनुस्तुर्य गोलकं चक्रम् ।
यष्टिः शकुर्घटिका कंपालक कर्तरी पीठम् ॥
सलिलं भ्रमीखलम्बः कर्णाश्छाया दिनार्धमर्कोयक्षः ।
नतकालज्ञानार्थं तेषां संसाधनात्यष्टौ ॥

Which means

There are seventeen types of *Kala-yantra* (time-reckoning instrument) these are:

1. Dhanur yantra (Bow instrument).
2. Turyagolaka yantra (Quadrant).
3. Chakra yantra (Circle).
4. Yasti yantra (Staff instrument).
5. Sanku yantra (Gnomon).
6. Ghatika yantra (A clock or a pot instrument).
7. Kapala yantra (Bowl instrument).
8. Karttari yantra (Scissor or Knif, cutter).
9. Pitha yantra (Seal instrument).
10. Salil yantra (water leveler).
11. Brahma or Sana yantra (For describeing circle).
12. Avalamba sutra (Plumb lines).
13. Karna or Chayakarna (A set of squares for diagonals).
14. Chaya or sankuchaya (Sun-dial)
15. Dinardha yantra (Midday measure instrument).
16. Arka yantra (Sun-instrument).
17. Aksa or Palasa yantra (Small degree measure instruments)].
18. From Salila, to the Aksa, these eight are used for adjustments and are basically important. According to Brhamagupta (see.)^[9].

सलिलेन संसाध्यं भ्रमेण वृत्तमवलम्बकेनोद्धोम् ।
तिर्यक कर्णानान्यैः कथितैश्च नत प्रवत्यामि ॥

Which means

Salila yantra: It is used for leveling; since a liquid such as water seeks its own level, it can be utilized to know whether a surface has been leveled or not.

Sanayantra: This instrument is used for drawing circles.

Avalambaka yantra: It is used for adjusting vertical line.

Karana: It is in used connection with angles and diagonals.

Dhanur yantra: It is used for nata and unata kala ghatikas.

Karttari yantra: This instrument is of the shape of a pair of scissors with two semi-circular blades, fastened to a string at the centre, at the centre is a fixed pole which casts shadows.

Chakra yantra: It is a circle of which the circumference (peridhi) is divided into 360 degrees. Provided with an axis at the centre perpendicular to its plane and suspended with a string. On the circumference (peridhi) of the cakrayantra are indicated the twelve rasis, ending up to Mina. The circle was used for finding zenith distances and longitudes. (see.)^[9].

4. Modern Astronomical Instruments

During the last 60 years, the old observatories and astronomical instruments at Kodaikanal Hyderabad have been modernized to an extent. At the same time new astronomical observatories research institutes and instruments have appeared on the astronomical map kavalur, Nainital, Japal Rangapur Gurusikhar and Udaipur cover night-time and day-time astronomy (see.)^[2, 5].

Modern astronomical instruments i.e., Radio-astronomical instruments like the Ooty radio telescope, ooty synthesis radio telescope, Millimeter wave radio telescope, the meridian circle, the chronograph, the sidereal clock, the mean clock, the quartz clock, the micrometer, the zenith telescope etc. play an important role in the Indian Space Programme, and in the determination of position of planets and minor and bodies of the solar system. The brief explanations are mentioned below. (See.)^[1, 2, 5, 8].

4.1 The Meridian Circle

An instrument known as the meridian circle measures the right ascensions and declinations of the principal heavenly bodies and astronomical clock are regulated with observations made by it. This instrument consists of a telescope mounted in such a way that it can move only in the plane of the meridian. At one end of the telescope there is an object glass and the other and an eyepiece to which an observer applies his eyes. In the focal plane in which the images of the observed objects are formed by the object glass, spider threads, called wires. There are two systems of wires one horizontal and an odd number of vertical wires arranged symmetrically about a central wire. These are two micro meters attached to the plate carrying these wires one capable of moving the horizontal wire parallel to itself and other capable of moving the vertical wires parallel to the central vertical wire (see.)^[1, 8].

The meridian circle and the sidereal clock enable us to measure the difference of the right ascensions of two bodies easily. The difference of the corrected times will give us at once the required difference in right ascensions.

4.2 The Clock

At least two clocks are kept in an observatory, the sidereal

clock and the mean clock. The construction is the same in both, but the pendulum of the mean clock is slightly longer, so that it keeps time, whereas the sidereal clock keeps sidereal time. (See.)^[1].

The rate of a sidereal clock is generally ascertained by finding the error of the clock from day to day, but can also be determined by finding the clock times of transit of the same star on two consecutive days. Comparing it with the sidereal clock and computing the mean time corresponding to the observed sidereal time require the mean clock.

The short clock consists of a simple pendulum, the rod of which is made an alloy of nickel and steel, because this metal is only negligibly affected by the changes in temperature. This instrument is housed in a room kept at a constant temperature by electricity. There is no hour or minute hand. The pendulum, called the master pendulum, is entirely free except that a small inclined plane is fixed to it on which a tiny roller roll down every 30 seconds to supply the little amount of energy, required to keep it going. The master pendulum is thus absolutely free all the time except when the roller is giving a little push for a small fraction of a second and that too only once in a 30 seconds. This is the secret of success of this instrument, which gives a daily variation of rate of the order of only one thousandth of a second cover a period of years with long term change of only one or two hundredth of a second. (See.)^[1, 2].

4.3 The Quartz Clock

The Quartz clock, developed fairly recently, is about ten times more accurate. In a quartz clock the hands are moved by an electric motor, the speed of which is accurate governed through an electric circuit by the vibrations of a small quartz plate. The two opposite faces of the plate are silvered and placed in an oscillating electric circuit. Power for this is taken from a battery, or the electric mains. The number of vibrations per second of the quartz is the order of a hundred thousand and depends chiefly on the thickness of the quartz plate. The quartz is kept in a chamber at constant temperature. (See.)^[1, 8].

4.4 The Chronograph

When the observer presses a button at the meridian circle, the time is recorded on an instrument known as the chronograph. In one form of the instrument, a tape runs at a uniform speed, and on it pin-pricks are made every second by a needle which is actuated by electric impulses sent out by the sidereal clock (see.)^[1, 2].

4.5 Radio-Astronomical Instruments

The Radio astronomy made its debut in India in 1952 when kodaikanal observatory built a 100 MHz radio telescope with a twin Yagi antenna for monitoring solar noise. In 1956, the observatory obtained a custom- built 10 cm wavelength radio receiver from the Common Wealth- Scientific and Industrial Research Organization, (CSIRO), Australia. In 1986 physical Research Laboratory (PRL) set up a radio telescope. Radio astronomical instruments came to its own in 1963 at Tata Institute of Fundamental Research (TIFR), Bombay. The first radio telescope under the new auspices was a grating-type radio interferometer, set up at Kalyan near Bombay, for observing the sun at 610 MHz with an angular resolution of

2.3 arcmin (see.)^[1, 2, 5, 8].

Radio-astronomical facilities now exist at Udhagamandalam (Ooty), Bangalore, Gauribidanur, Thaltej in Ahmedabad and at the small village of Khodad near Pune.

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