

Tracking the Heavens

Astronomical Instruments in Ancient India

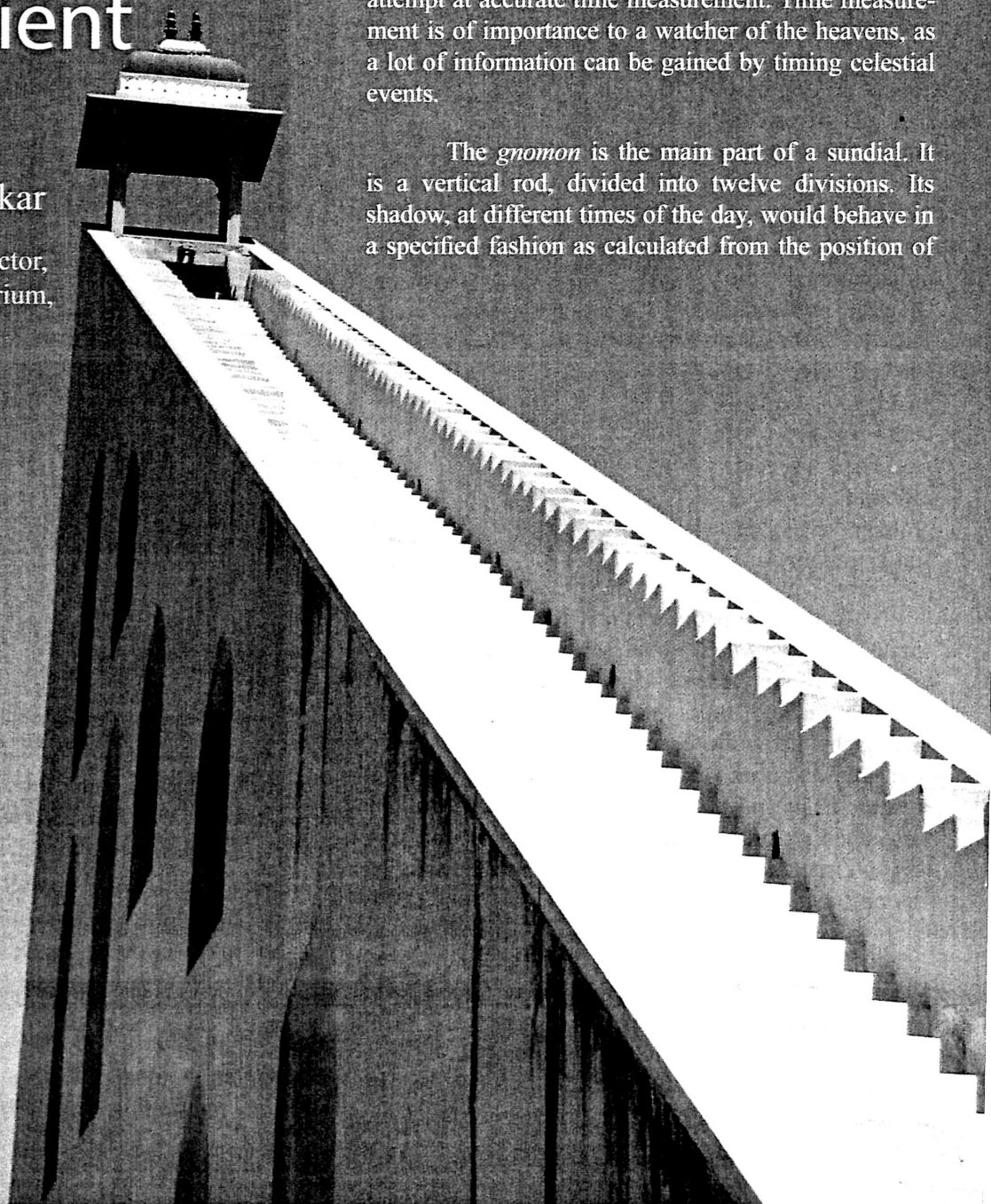
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Astronomy is an observational science. An astronomer observes the heavens and tries to interpret what is seen. So, anything that helps in the process of observation is useful. It is why astronomical instruments have assumed so much importance. Four hundred years ago, Galileo Galilei first used the telescope for observations. Since then, the telescope and astronomy have become inseparable.

Astronomy is, however, much older than the telescope and there were several millennia of astronomical observations with the naked eye. However, there were other instruments used to aid the human eye. In the context of the Indian tradition, two, the *clepsydra* and the *sundial*, can be highlighted. The *Surya Siddhanta*, (XIII, 23) for example, describes how the former is made - "a copper vessel, with a hole in the bottom, set in a vessel filled with pure water, sinks sixty times in a day and night, and is an accurate hemispherical instrument." In short, it is an attempt at accurate time measurement. Time measurement is of importance to a watcher of the heavens, as a lot of information can be gained by timing celestial events.

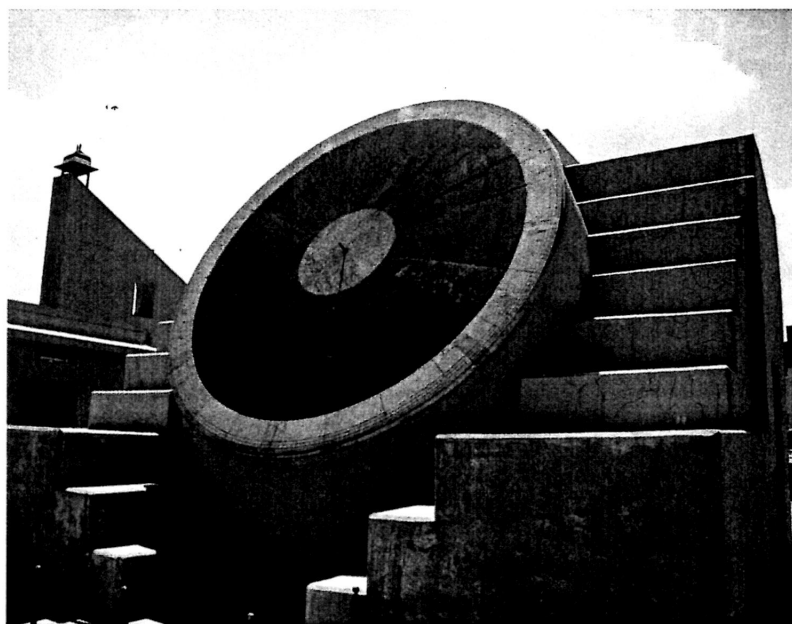
The *gnomon* is the main part of a sundial. It is a vertical rod, divided into twelve divisions. Its shadow, at different times of the day, would behave in a specified fashion as calculated from the position of



the Sun in the sky. Details of construction are given in books like the *Surya Siddhanta*. These relate, not to the method of constructing the instrument, but on how to interpret its observed behaviour.

There were other instruments too, though not so commonly used. The same book, for example, gives elaborate instructions on the making of an *armillary sphere*. This sphere is a model of the star-studded sky, on which the constellations are marked. It shows the path, along which the Sun is observed to travel, as viewed from the Earth. In a way, this is the sky-equivalent of the earthly globe on which different countries are mapped.

Another old instrument, the *astrolabe*, consists of a hollow disk, called the *mater* (mother), which is deep enough to hold one or more flat plate(s) called a *tympan* or *climate*. Above the *mater* and *tympan*, the *rete*, a framework bearing a projection of the plane of motion of the Sun and several points indicating the positions of the brightest stars, is free to rotate. The *astrolabe* is however of Greek origin and may have come to India through the Greek invasions. The *astrolabe* was effectively an analogue calculator, capable of working out several different kinds of problems in spherical astronomy.



The Narivalaya

In the Jaipur observatory, there are two large single disc *astrolabes*, about seven feet in diameter, one made of sixty sheets of iron riveted together and the other made of brass, patched up with lead. These instruments show the interest that the ruler of Jaipur, Maharajah Sawaai Jai Singh, had in astronomical measurements and computation of data. The *astrolabe* was called *yantra raja* in Sanskrit, meaning, the king of yantras, indicating the place of honour it enjoyed amongst astronomical instruments.

Raja Sawai Jai Singh, born in 1686, owed allegiance to the Moghal ruler at Delhi. Apart from being a soldier and a diplomat, Jai Singh had a great liking for astronomy, which was unusual for a ruler of those times. The story has it that in 1719, he was witness to a noisy discussion in the court of the

Moghal Emperor at Delhi. The heated debate was on how to make astronomical calculations to determine an auspicious date for the Emperor to embark on a journey. This discussion led Jai Singh to think that the nation needed to be educated on the subject of astronomy. He then got several related treatises from Europe, like Euclid's *Elements*, translated into Sanskrit. These were books needed for astronomical computations. His own contribution to astronomical database was the astronomical tables, published under the name *Zij Muhammad Shahi* (so named to honour the Moghal Emperor). It is interesting how a superstitious belief in the so-called auspicious hour being defined through stellar configurations, eventually led to genuine scientific work.

Jai Singh's most spectacular achievement was the erection of observatories in different Indian cities. Although the invention of the telescope and its use for astronomy were well set in Europe, there

was, however, no indication of this revolution at Jaipur. Jai Singh instead opted for the earlier tradition of huge masonry instruments. A few centuries earlier, Ulugh Beg, at Samarkand, had built an observatory, which seems to have inspired Jai Singh, although he added his own instruments to the collection. He erected observatories in Jaipur,

Delhi, Mathura, Banaras and Ujjain, the first two being the big ones.

The masonry instruments at Jaipur include the *Samrat Yantra*, *Jai Prakash Yantra*, *Ram Yantra*, *Digamsha Yantra*, *Dakshinovritti Yantra*, *Nari-valaya Yantra*, *Vritti Shashtamshaka*, *Rashi-valaya* and *Kapala*. The last two may have been completed after Jai Singh's time. These yantras were aids to observation of stars at night and the Sun in daytime. The word 'yantra' may be loosely translated as a machine.

The most impressive of these is, as its name implies, the *Samrat Yantra*, is the 'emperor' amongst the yantras. A modern replica was built in the early 1990s in the premises of the Inter-University Centre

for Astronomy and Astrophysics (IUCAA). The Yantra, is in fact, a giant sun-dial. The structure is dominated by a triangular gnomon whose shadow falls on one of the two circular quadrants. Technically, the hypotenuse of the triangular gnomon is parallel to the Earth's axis of rotation and thus, points (in the northern hemisphere) towards the Pole Star or the Dhruva star in the Indian jargon. Likewise, the circular arc is parallel to the Earth's equator.

The sundial is expected to tell us the local time from the position of the shadow of the gnomon under sunlight, on the quadrants. This expectation is, however, rather simplistic as several technical factors intervene and make the relationship of local time to the extent of the shadow, rather complicated. Hence, a table of corrections is usually made available to the observer. Of course, so far as measurement errors are concerned, the larger the yantra the greater the accuracy. Jai Singh, to his credit, seemed aware of the concept of measurement errors.w

The *Jai Prakash Yantra* has been termed by Jai Singh's astronomy assistant, Jagannath, as the 'crest jewel of all instruments'. It is believed that Jai Singh himself had the idea of its design and as such, it is new and original in relation to Ulugh Beg's observatory. It is hemispherical and in its inner 'concave' side are mapped certain coordinates. Cross-wires are stretched across the diameter plane of the hemisphere and the key thing to observe is the shadow of the cross-wires on the hemispherical base. From these shadows, in relation to the coordinates marked, the Sun's position in the celestial sphere can be worked out.

Other heavenly bodies can be observed by placing the eye at the 'proper graduated point', and observing the passage of the body across the point of intersection of the wires. In a way, these yantras are able to cut across the complex geometry and dynamics of the solar system, and provide an analogue way of describing the problem.



The *Jai Prakash Yantra*

Impressive though these instruments are, they had already become irrelevant at the time they were constructed. For astronomy, with the aid of telescopes, was making rapid advances. France, Britain and Italy had centres where telescopic astronomy was pursued. It is rather unfortunate

that Jai Singh's European advisers did not come from these countries but were from Portugal, where telescopes for astronomy had not made headway. He seems to have been advised that telescopes do not give accurate observations and so felt it 'safe' to continue with the masonry instruments, making them huge in the interest of accuracy.

Jai Singh died in 1743. In 1764, Delhi was plundered by Jawahar Singh, the son of the Jat King, Suraj Mal of Bharatpur, and the Delhi observatory was severely vandalized. A more telling commentary on the lack of appreciation of astronomical science amongst the rulers comes from the historical development, in which Jai Singh's grandson converted the Jaipur Observatory into a gun factory, with his ancestral large *astrolabe* used for target practice. Today, rather than places for astronomical observations, the 'Jantar Mantar' at Delhi and the Jaipur Observatory are popular tourist spots.

The *Yantra Raj (Astrolabe)*

