Teaching laboratories for Positional Astronomy

The Jantar Mantar Observatories of India

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Jai Singh, the astronomer king who constructed the Jantar Mantar observatories early in 18 century, had two usages in his mind when he set out for the construction of these positional astronomy instruments. – One, he wished to have accurate instruments with which he could determine celestial positions with precision. And, two – he has also clearly stated his intention in building the observatory as a means of ensuring that the common citizen would find it easy to understand how astronomers do these observations.

Figure 1 : A view of the Chakra Yantra of the Jaipur Observatory, with the Equinoctial sundial the Laghu Samrat Yantra in the background.

These instruments are like walking through three dimensional spherical trigonometry and they do bring basic astronomy alive to those who have a beginner's interest. It is very easy for anyone to appreciate the beauty and simplicity of celestial observations, using these instruments, once a little guidance is given by a trained astronomer.

For the Delhi Observatory, the first public observations in modern times, were taken with these instruments in March 2004 as part of educational activities related to the Transit of Venus. The observations consisted of measuring the maximum elongation of Venus just prior to its transit across the disk of the Sun. These observations, co-ordinated by Nehru Planetarium, New Delhi, were done successfully with reasonable accuracies, inspite of the fact that the markings on these instruments are missing. The instruments of the Jaipur Observatory are better maintained, and their usage for a gathering of a database of astronomical observations to characterize the instruments, is a more easily feasible project.

The basic structures of the Jantar Mantar instruments are yet reasonably preserved. Whatever damage has happened to the instruments is mostly surface damage which can be repaired. The Jaipur instruments are the best maintained, although, there are concerns with respect to the maintenance, condition and sustained usage of all the four Jantar Mantar observatory instruments - those at Delhi, Jaipur, Varanasi and Ujjain.

The Observatories have the potential to be a live teaching laboratory. Any modern day student of Astronomy and Astrophysics would need to know the basics of positional Astronomy, and would do that learning very well, from these observatories.

The Samrat Yantra, an equinoctial sundial, was evolved into a serious positional astronomy instrument by Sawai Jai Singh, and was installed by him in each of the Jantar Mantar Observatories that he had built. The largest at the Jaipur Observatory and the second largest at the Delhi Observatory, were both marked at some time, with a least count of 2 seconds for measurement of time.

There have been serious criticisms of realistically achieving this accuracy, given the uncertainty in shadow reading from the penumbra. However, in December 2006, it was practically demonstrated for the Samrat Yantra of the Delhi Observatory that achieving 1 second accuracy in time measurement is a feasibiliy even in its current state of disrepair, absence of markings and presence of so many masonary irregularities.

This demonstration was made by a group of observers from the Nehru Planetarium, New Delhi and amateur astronomers, working over a period of three months, to make a temporary observational calibration of the Samrat Yantra, for every minute. A public observation festival was then held on the Winter Solstice day where time measurements obtained by the visitors and school students were compared with a clock set to 1 second accuracy with kind help from the National Physical Laboratories, New Delhi.

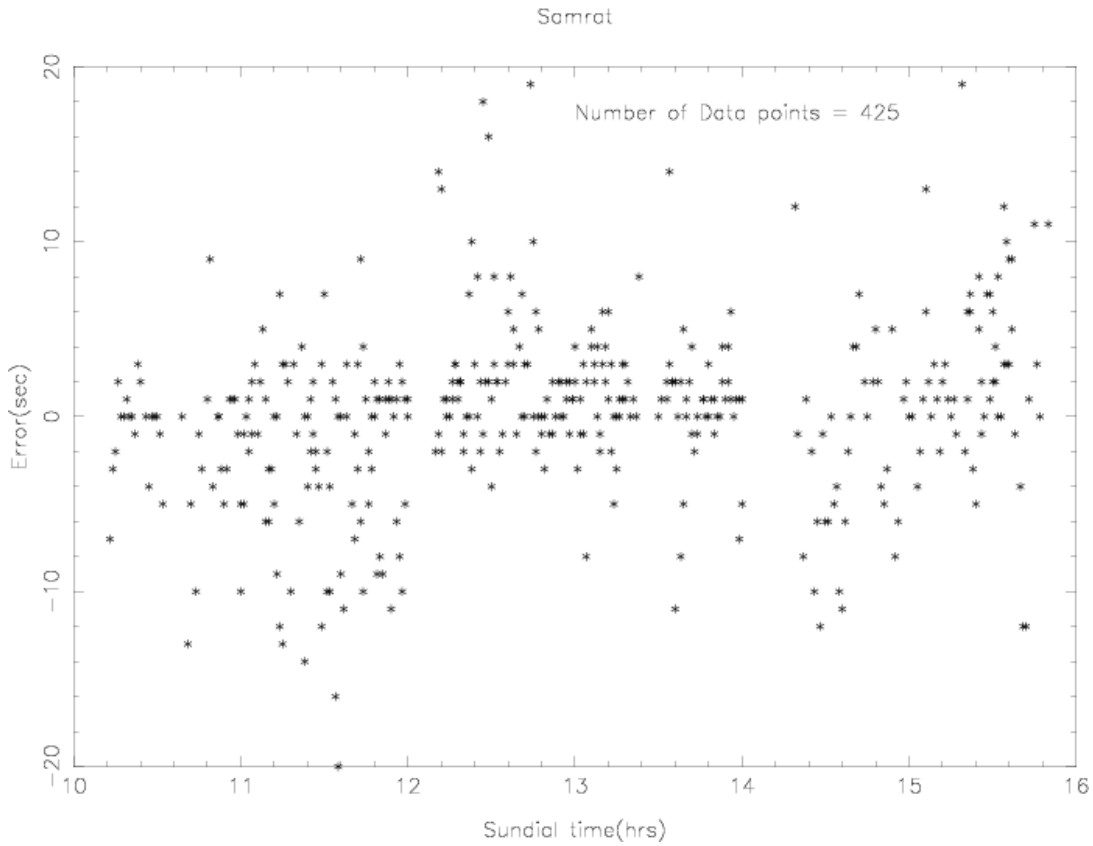

Figure 2: Error in time obtained from using the temporarily calibrated Samrat Yantra as a sundial. The observations were conducted by groups of students and amateur astronomers.

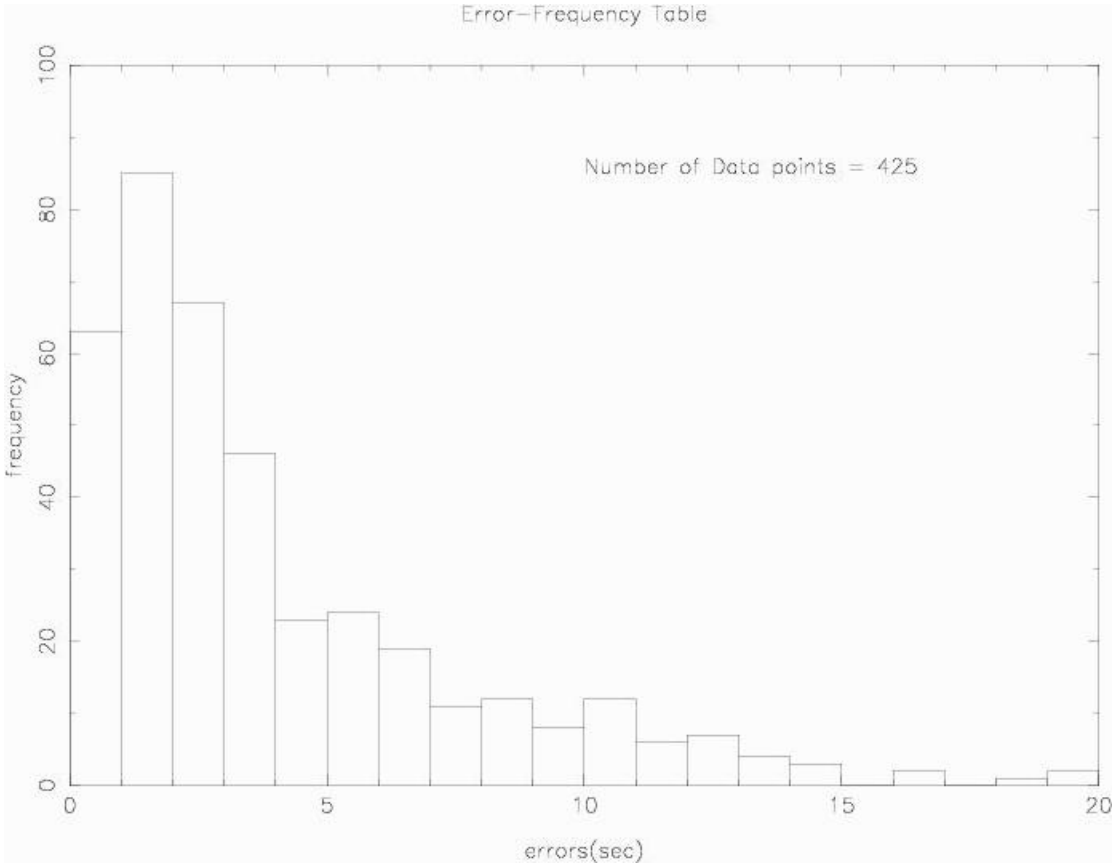

Figure 3: A histogram of the number of data points with different errors in measured time. The data is the same as in Figure 1.

The Misra Yantra of the Delhi Observatory is a unique teaching instrument for positional Astronomy, thought to have been built, not by Sawai Jai Singh, but, by his son Madho Singh, who also had some astronomy interest. The instrument does

The most recognised aspect of this instrument is the arched marble Niyat Chakra which defines its front elevation. These measure the Declination (angular distance from the celestial equator) of the Sun and other celestial objects in a beautifully simple manner.

Figure 4: A view from a little to the South East, of the Misra Yantra, during March Equinox day activities being conducted in 2005.

The other functionalities of the Misra Yantra include time measurements similar to the Samrat Yantra, measurement of Meridian Altitudes using the Dakshinottara Bhitti Yantra and the measurement of Ecliptic co-ordinates using the Karka Rasi Valaya instrument on the back wall of the Misra Yantra.

There are the Ram Yantra instruments of the Delhi and Jaipur observatories which make Altitude and Azimuth measurements of the Sun and celestial objects seem like a fun game being played by children crawling around under the aesthetically pleasing wall and floor sectors of these cylindrical instruments. There are the bowl shaped Jai Prakas and Kapala Yantras which can measure celestial co-ordinates in many different co-ordinate systems and are complete positional astronomy instruments, in some sense. One of the Kapala Yantras at the Jaipur observatory has also a built in capability for theoretical conversions between different co-ordinate systems. There is the Chakra Yantra for measuring equatorial co-ordinates of celestial objects whose mounting is akin to a modern day equatorially mounted telescope.

There is another aspect to be bought out, about the Observatories. We have been working with the calibration of the Samrat Yantra of the Delhi Observatory, for its usage as an equinoctial sundial. The amazing practical result that we found was that, even with very temporary calibration markings made in chalk, the Samrat Yantra of the Delhi Observatory, is capable of reading time to an accuracy of 1 second. With more permanent calibration markings, it should be able to better this accuracy. This aspect needs to be studied, analysed and emphasised more. The world over, 1 second accuracy in time keeping was achieved around 1720s. At that time, India also had an instrument that was capable of achieving 1 second or even better accuracy in time keeping.

For 300 years this fact had not been appreciated in practice, although theoretical statements about the accuracy of these instruments are scattered in all the guide books. Every day there are hundred of visitors passing through the Observatory – not being able to appreciate this practically, even today.

For this appreciation, a complete restoration with all markings in place is needed for the Delhi Observatory. What is also needed is a very large sized modern day digital clock – set accurate to 1 second precision by the National Physical Laborotories – on display near the Observatories. This clock should be visible from all the instruments of the observatory, and every day's visitor would then be able to appreciate the accuracies of these beautiful instruments.

Table 1: Comparison of Identifiable Observatories up to the 18th century (prepared by DRONAH, for tentative listing of the Jantar Mantar Observatories for the World Heritage list, under the Astronomy and World Heritage initiative.

Name of Observatory	Present Status	Emphasis on large scale instruments	Construction Material			Type of Observatory		Date of Origin						
			Megaliths	Masonry	Metal	Pre-Telescopic	Post-Telescopic	Pre 13th Cent.	13th Cent.	14th Cent.	15th Cent.	16th Cent.	17th Cent.	18th Cent.
Stonehenge, United Kingdom	Megaliths on site. On WHL as Stonehenge, Avebury and asoociated Sites							3100 BC						
Observatory of Nasir-ud-din Al Tusi at Maragheh, Iran	Archeological remains								1259					
Gaocheng Astronomical Observatory, China	Well preserved								1276					
Ulugh Beg's observatory at Samarkand	Archaeological remains present. On WHL as part of Samarkand										1425			
Beijing Ancient Observatory, China	Well preserved, on Tentative World Heritage List										1442			
Istanbul observatory of Taqi al-Din, Turkey	Destroyed in 1580											1577		
Tycho Brahe's Observatories, Sweden	Destroyed in early 1600's. Archaeological remains											1580-1584		
Royal Greenwich Observatory, United Kingdom	Well preserved												1675	

Jantar Mantars; Astronomical Observatories of India	Well preserved instruments													1718-1734

On World Heritage List/ Tentative List