author can write one more book after a couple of years.

Once again, for anyone seriously interested in understanding the story of Indian IT, this book is a 'must read'.

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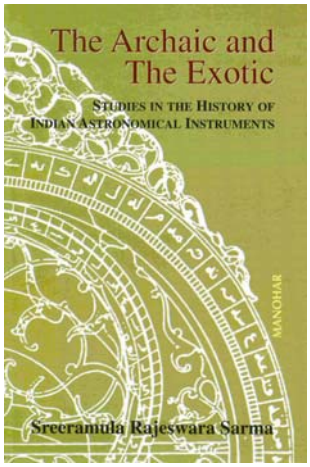

The Archaic and The Exotic: Studies in the History of Indian Astronomical Instruments. Sreeramula Rajeswara Sarma. Manohar Publications and Distributors, 4753/23 Ansari Road, Daryaganj, New Delhi 110 002. 2008. 319 pp. Price: Rs 795.

We hear a lot about the astronomical observatories of Sawai Jai Singh, about the beginnings of modern astronomy in India, and about the theoretical contributions by Indian astronomers – from Aryabhata to Bhaskara to Kamalkara. There is less available material about astronomical instruments and their usage from early times, to the beginnings of modern astronomy in India.

Some information about early astronomical instruments is compiled by Subbarayappa and Sarma[1], a chapter of which gives extracts from the works of Indian astronomers related to instruments and their usage. There is some information with details of a few individual instruments in the works of Ansari and Khan Ghori[2], Sarma *et al.*[3].

The work of Sreeramula Sarma, filling this gap, is also of interest due to the fact that there is a general view that historically, Indian astronomical endeavours have always been more on the theoretical side, while actual instrumentation and observations had taken more of a backseat, until the (poignantly anachronistic) efforts of Sawai Jai Singh.

However, intricate astronomical instrumentation (some utilitarian and some valued more for their exquisite craftmanship or innovations in construction) seems to have existed in the last millennium in various corners of the country, whose evidence has been lying forgotten in dusty museums.

Through painstaking work, Sarma has put together a comprehensive view of astronomical instruments used in India before the time of Sawai Jai Singh. It makes for an exhilarating reading – getting to know a wealth of information about the archaic as well as the exotic astronomical instruments made and used in India from the times of Brahmagupta, in Feroz Shah Tughlaq's times, instruments in Mughal miniatures, exquisite astrolabes and celestial globes!

One aspect that would have added a quantitative element of interest to the description of the instruments mentioned in all the chapters of the book, is the actual accuracy in measurements by the extant specimens of instruments. Such a quantitative look is rather difficult, perhaps, in the Indian context, where observational results have not been recorded for the most part. The accuracies in the depictions of the stars in the extant astrolabes, or accuracies with any of the extant measuring instruments if touched upon, would have added an additional, but necessary element of interest.

The division of the book into the four segments – (1) The context (2) Water clock (3) The astrolabe and (4) The celestial globe, from the various research articles by the author, seems a useful roadmap. The first paper in this series gives a listing of sources and extant instruments, digging out many obscure references and describing instruments from worldwide museums. There are questions that one wishes were addressed, even if not answered.

How much of actual usage did these instruments see? What were the accuracies of these instruments? What was being done by the observers to correct accumulated errors in water clocks and the differences from seasonal hours? What was the status of knowledge about the equation of time at the time of usage of these instruments? These questions do not find any place in the book, perhaps also because it is precisely these questions that are so difficult to ask, let alone answer, when it comes to Indian records of early observations and instruments.

Detailed descriptions on the manufacture of astrolabes and celestial globes as a part of the author's catalogue in preparation, is a useful guide to follow up in detail, to see whether any of these instruments were used with some seriousness for observing and their resulting accuracies.

From the workmanship point of view, there are interesting discussions about the instruments. For instance, the universal astrolabe manufacture and the unusual celestial globe manufactured for Aurangzeb, which when lit from inside, would show a glowing celestial sphere through the drilled holes for the star positions (the first planetarium in India).

The chapter on the astronomical instruments in the *Brahmasphutasiddhanta* discusses nine instruments mentioned in the 'Yantradhyaya' chapter by Brahmagupta. It however, does not mention the Armillary Sphere that seems to have been discussed by Brahmagupta in the Goladhaya of the *Brahmasphutasiddhanta*, a teaching instrument more complex than the simple measuring instruments discussed in the Yantradhyaya. However, the conclusion drawn, that the measuring instruments were confined to the rather simple versions, while flights of fancy in discussions of possible automated time-measuring instruments as well as perpetual motion machines in the *Brahmasphutasiddhanta* as well as other Siddhantic works, might well have to be accepted. This actually seems to indicate that the measuring instruments mentioned – the Dhanus, Turyagola, Cakra, Yasti, Sanku, Ghatika, Kapala, Kartari, and Pitha – were actually built and used for observations by the authors who wrote about them, a point perhaps at variance with the conclusion drawn from this chapter in the book.

One interesting chapter in the book deals with the astronomical instruments in Mughal miniatures. The Mughal miniatures, which depict either a ring dial or a chuda yantra, water clock, or a sandclock, are all described in detail and the near absence of astrolabes in Mughal

miniatures is lamented. It also seems lamentable that the Mughal miniatures reflect only the astrological interest of the emperors and do not in any way reflect on the fact that some of the Mughal emperors were quite keen observers of the skies, and had also made many quantitative measurements. One reads in various references, of Babur's measurements of the altitude of the Pole star from Chanderi, Jehangir's observations of a solar eclipse with an estimation of the obscuration fraction, and his observations of comets. Perhaps there were many more such observations that never entered the chronicles, and the interest of the Mughal emperors in actual astronomical observations does not seem to be reflected in the miniatures in any way. With the result that a scanning of the Mughal miniatures and possible representations of astronomical instruments in them, leaves one with an overwhelming image of the Mughal world being steeped in superstitions related to astrology, with no interest in real astronomy. Perhaps, the author could have corrected this impression through a discussion of observational activities that do not enter the world of the Mughal miniatures.

The description of the history of water clocks and, in particular, that of the sinking bowl-type of water clocks which seem to have originated from the Indian subcontinent, is interesting. Its descriptions are known from the time of Buddagosa, Aryabhata, Varahamihira, Lalla and Bhaskara to Visrama's *Yantrasiromani*, written in AD 1615. Bana's *Kadambari*, also has a description of the method for announcing the 'ghatis' and 'pahars'.

From an astronomical point of view, the aspect of utmost interest is to know in what way, if any, did the early users of the water clocks, read the clocks with respect to the changing seasonal hours. Herein would lie the entire positional astronomy understanding of that period! However, this aspect is completely ignored in this chapter, apart from mentioning that various systems have existed for reconciling the varying pahars with the fixed ghatis. How were these determined before they were reconciled in the way of announcing the time? There must have been a combination of water clocks and sundials used to determine the equation of time accurately, and thus distribute the day in terms of equal ghatis and the unequal pahars. What were the observational means of doing this and what were the possible accuracies? The book discusses the description by Visrama in his *Yantrasiromani*, of practically ensuring the accuracy of the 'ghatika yantra' by checking that the bowl sank sixty times in the time from one sunrise to the next. This however, would then have to be tested around the equinox days. Did Visrama specify this in his *Yantrasiromani*? Did the different authors talking of the ghatikayantra also talk of the method of determining the difference between the equal ghatis and the unequal pahars for every day of the year? Lack of discussion on this issue is disappointing.

There is a description also of I-Sing's visit and his appreciation of the water clocks that he had seen at Gaya, Nalanda and Kusinagara, and his desire that such water clocks be set up at the monasteries in China, so that time-keeping would be a possibility even in inclement weather. From this, one might conclude that there must have been a good system in place in all these watches being maintained through water clocks, of reconciling the equal time-keeping of the water clocks with the unequal seasonal hours.

From the discussions in the book, it is interesting to note the widespread usage of the sinking bowl-type water clock in India, both in terms of geography as also in terms of centuries of its usage in India, in some cases extending to the 19th and the 20th centuries. From the lore of Bhaskaracharya using such a ghatika yantra to determine a possible auspicious moment for the marriage of Lilavati, his daughter, to the fifteenth century *Jaiminibharatamu* of Pillalamarri Pinavirabhadra, and his charmingly oblique reference to a water clock by comparing the half moon on Shiva's head to a water clock which he came equipped with, being impatient for the time of his union with Parvati, to the nineteenth century references of Meer Hussain Ali's English wife who infers that the sinking bowl clock and the method of announcing time must have been introduced into England, from the East, to the tale of Rudyard Kipling's father who frustrated with the regular malfunctioning of modern clock at the Lahore museum, installed a water clock to take its place, to the story of the survival of the usage of water clocks all the way until 1973 in the town of Sehwan, in Sind, Pakistan – it is indeed a widely spread spectrum of water clock usage in geography and time.

The detailed descriptions of variations in the way a water clock was to be set up for determining the auspicious time of marriage, in different manuscripts, give an idea of the way, something so utilitarian as a method for determining the time gets garbled in ritual, losing perhaps, in that process, the original utility itself.

The book discusses the improvements bought in by Feroz Shah Tughlaq and Babur in the ways of announcing the time, through the usage of these water clocks. However, an improvement in the method of announcement would not in itself merit their names being remembered in the history of time-keeping, in particular, that of Feroz Shah Tughlaq and his invention of the Tas-i-Ghariyal. The Tas-i-Ghariyal invented by Feroz Shah Tughlaq could not just have been a new way of announcing time, as discussed by the author? There must have been an improvement obtained in the accuracies of the known equation of time and the method of tying this up with a reconciliation of the equal ghatis of the water clocks with the unequal seasonal hours. That this was so, is attested by the chronicler who wrote the *Tarikh-i-Firoz Shahi*. He repeatedly mentions that the invention of the Tas-i-Ghariyal ensured that the faithful had the correct time for prayers and in particular, the time of the sunset for breaking the 'Roza' correctly, even when clouds prevented them from observing the sunset. He also states that the invention of the Tas-i-Ghariyal contained the rules for understanding the hours of the day and night, and also clearly mentions the usage of shadow movement with respect to the Tas-i-Ghariyal. All this leads one to conclude that the invention of the Tas-i-Ghariyal by Feroz Shah Tughlaq perhaps involved the combined usage of a water clock and a device for determining the correlation factor between the equal ghatis and the sunrise–sunset timings as they vary through the year. This is something that needs further study.

Collecting together several articles from journals, the book gives a comprehensive idea to anyone interested about the astronomical instruments prevalent in India before Sawai Jai Singh's time. The book looks at two streams of instrumentation – a continuing archaic tradition and a more open receptiveness to the introduction of exotic instruments like astrolabes and celestial globes from elsewhere in the world. There exists no other com-

prehensive resource in this area and thus, the book will fill this void.

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