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Scientific instruments in pre-modern India and the global circulation of knowledge

No comprehensive and authoritative history of science and technology of India has till today been written that would be even remotely comparable to the achievement of Joseph Needham (1900-1995) for China, through his still continuing series *Science and Civilisation in China* or SCC (1954-). One of the reasons is no doubt that much substantial spade work on the history of science and technology in India remains to be done before such an encyclopedic project can be undertaken.

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Sreeramula Rajeswar Sarma, 2008.
The Archaic and the Exotic: Studies in the History of Indian Astronomical Instruments
Delhi: Manohar Publishers, 319 pages.
ISBN 978 817304571 4.

JUST AS MUCH OF HIS OTHER RESEARCH, the present work of Prof. Dr. Sreeramula Rajeswara Sarma would provide a reliable basis at least for important sections of an SCC-like history of science and technology of India. This also applies to a still ongoing project of Prof. Sarma's, a descriptive catalogue of "all extant Indian instruments in all private and public collections in India and abroad, with historical surveys of the development of each instrument-type, its use and geographic spread, and a full technical description of each" (Sarma, *The Archaic and the Exotic* [AE], p. 27).

Sarma's AE contains fifteen chapters divided over four parts. The author explains the title as follows: "The history of astronomical instrumentation in India is dominated by two mutually contradictory – yet complementary – currents: on the one hand the resilience of certain archaic instruments that held sway for long even after they had become obsolete; on the other, Indian astronomers' receptivity to exotic instruments from other cultures. Hence the title of the volume: *The Archaic and the Exotic*" (AE, p. 13).

The 'Needham Question' and India
With regard to China, the 'Needham Question' has been discussed on several levels: Why did advanced science and technology emerge in the West and not in China (esp. in the light of the high level of science and technology China had in comparison to Europe till the seventeenth century)? The question has been extended to India, as India, too, possessed a high level of science and technology in comparison to Europe. This problem area has been defined by Samuel Huntington as "The Great Divergence".

With regard to the dimensions of economy and state organization, Kenneth Pomeranz (in *The Great Divergence,* Princeton Univ., 2000) formulated a reply to Needham's (and Huntington's) question according to which the question itself is asked on the basis of wrong presuppositions. The entities compared – Europe and the Orient: China, Southeast Asia, India, etc. – had never been truly independent as there were important similarities and pre-existing connections. Similar doubts arise with regard to science and technology. Because of its importance for the ongoing 'Divergence' discussion (see, for instance, Benner and Isett in *Journal of Asian Studies*, 61.2 (2002): 609-662 for an attempt to refute Pomeranz), I will continue with a brief discussion of a topic in Sarma's book that is particularly relevant to the pre-modern global circulation of knowledge.

The Design of Perpetual Motion Machines in India: Lynn White Jr.'s thesis
A perpetual motion machine (Latin *perpetuum mobile,* Sanskrit *ajasra-yantra*), in the words of Sarma (AE, p. 64-65), "is a device that is supposed to perform useful work without any external source of energy or, at least, where the output is far greater than the input. The idea of constructing such machines and of employing the power generated by them has fascinated the minds of many inventors in Europe since the Middle Ages. Modern science says that it is impossible to construct such machines and ridicules the attempts as mere flights of fantasy."

Lynn White Jr., to whom Sarma refers, had pointed out (*American Historical Review,* vol. LXV: 522) that a "significant element in Europe's thinking about mechanical power" had been supplied to Europe from India: the concept of perpetual motion. White attributes this concept to "the great Hindu astronomer and mathematician Bhāskara" who, writing around C.E. 1150, "describes two gravitational *perpetua mobilia.*" Somewhat simplistically, White (ibid. 523) believed that in India the idea of a *perpetuum mobile* "was consonant with, and was probably rooted in, the Hindu belief in the cyclical and self-renewing nature of all things."

White could see that Bhāskara's idea of a *perpetuum mobile* "was picked up in Islam, where it amplified the tradition of automata, inherited from the Hellenistic age". An "Arabic treatise of uncertain date", but which "in the manuscript collections is associated with the works of Ridwan (ca. [C.E.] 1200), contains six perpetual motion machines, all gravitational. One of them is identical with Bhāskara's mercury wheel with slanted rods, whereas two others are the same as the first two perpetual motion projects to appear in Europe: the architect and engineer Villard de Honnecourt's wheels of pivoted hammers and of pivoted tubes of mercury of about 1235.
In an anonymous Latin work of the later fourteenth century we find a *perpetuum mobile* very like Bhāskara's second proposal, that is, a wheel with its rim containing mercury. We may thus be sure that about [C.E.] 1200 Islam transmitted the Indian concept of perpetual motion to Europe, just as it was transmitting at the same moment Hindu numerals and positional reckoning: Leonard of Pisa's *Liber abaci* appeared in 1202." The reception of the idea of perpetual motion in thirteenth-century Europe, according to White (ibid. 523), stood in a marked "contrast to India and Islam", as in Europe there are "indications of intense and widespread interest in it, the attempt to diversify its motors, and the effort to make it do something useful".

Two parties of opposition against Lynn White's thesis
Lynn White's thesis which attributes the idea of perpetual motion and hence the foundations of modern power technology to a 12th century Indian text by Bhāskara was, as Sarma points out, "contested from two sides, one holding that such machines were known to the Arabs long before Bhāskara's time, and the other claiming that both the Indian and Arabic accounts owe their inspiration to China".

In their *Islamic Technology: An Illustrated History* (Cambridge Univ., 1986), Ahmad Y. Al-Hassan and Donald R. Hill argue (p. 68) that the Arabic technical descriptions and the illustrations found there are quite elaborate and constitute a single approach. Hence, the occurrence of one or two perpetual motion wheels in the Indian text would not have implied a case of transmission from one culture to another. Al-Hassan and Hill do accept, however, that there was an important transmission from the Arabic descriptions to the West.

Joseph Needham represents the other party of opposition to Lynn White's view. He praises Lynn White, judging that in his study on sources of Western medieval technology he "has done a good service by pointing out that in correct historical perspective, the idea of perpetual motion has heuristic value" (J. Needham in SCC vol. IV part 2:54). However, Needham wants to derive the idea of a perpetual motion machine from "Indian monks or Arabic merchants standing before a clock tower such as that of Su Sung and marvelling at its regular action" (J. Needham in SCC vol. IV part 2: 540). Not surprisingly, Lynn White was not impressed by the reference to the 11th century astronomical clock tower of the Chinese polymath Su Sung (based on a water clock of the outflow type) and dismissed Needham's suggestion as "lacking in any evidence" (AE, p. 69).

Neglected textual evidence regarding the perpetual motion machines
Having indicated the outlines of White's thesis and the opposition it received, Sarma continues: "The astonishing thing about this debate – like many other debates concerning India's past – is that it is conducted on the basis of just two Sanskrit texts which happen to be available in English translation, ignoring all other texts. Lynn White traces the idea of the *perpetuum mobile* to twelfth-century India on the basis of Lancelot Wilkinson's translation of the Siddhāntaśiromaṇi, while Needham's comments emanate from his perusal of Ebenezer Burgess's rendering of the Sūryasiddhānta. The passage cited by Needham does not even discuss the *perpetuum mobile.*" Even Lynn White's sources are characterized as insufficient: "No doubt, Lynn White's conclusions are highly perceptive even with the limited sources available to him, but in history of technology there are no shortcuts. One has to study all the relevant original texts, and the material remains if there are any, and interpret the data in the correct space-time framework." In the present case, Sarma shows in the sequel to this chapter that "a study of the original texts not only upholds Lynn White's view, but even strengthens it further".

The crucial evidence of the Sanskrit sources pertains to two kinds of automatic devices, "both called *svayaṁ vaha yantra*, 'self-propelled machines'. In the first variety, an outflow type of water clock causes a solid sphere to rotate around its axis once in 24 hours, thus simulating the apparent motion of the great circles in the heavens" (AE, p. 70). It is a teaching instrument described for the first time by *Āryabhaṭa*, about the beginning of the sixth century C.E.

It is the second variety, however, that can be regarded as a (hypothetical) *perpetuum mobile* that is supposed to turn for ever without any external input. Sarma finds that evidence for this is much older than White thought and than was accepted by Al-Hassan and Hill or by Needham: the *perpetuum mobile* had been described for the first time not less than half a millenium earlier. Brahmagupta, another great mathematician and author of the Brahmasphuṭasiddhānta, completed in C.E. 628, gave the "first systematic treatment of the construction and use of a large number of scientific instruments" including the *perpetuum mobile*. In the words of Brahmagupta, its description is as follows: "Make a wheel of light timber, with uniformly hollow spokes at equal intervals. Fill each spoke up to half with mercury and seal its opening situated in the rim. Set up the wheel so that its axle rests horizontally on two [upright] supports. Then… the wheel rotates automatically for ever" (AE, p. 70; see figure 1).

Here it is to be noted that Brahmagupta's mercury wheel is much earlier also than Su Sung's clock tower (C.E. 1090). The question of any Chinese or Indian monk transmitting the knowledge of Chinese automatic clocks to Indian astronomers like Brahmagupta therefore does not arise, "contrary to what Needham would like to believe" (AE, p. 73). On the other hand, Brahmagupta's work is known to have been transmitted to the Islamic world in the second half of the eighth century.

Categories of scientific instruments
The list of categories of Indian scientific instruments which Sarma envisages for his catalogue in preparation and discusses in his book (AE, p. 27) gives a good impression of the varieties of Indian instruments available in- and outside India: water clocks (outflow and sinking bowl type) and sand clocks, Indo-Persian and Sanskrit astrolabes (such as that in Figure 2), and ring dials and celestial globes (as in Figure 3). Of the *perpetuum mobile*, not surprisingly, only designs are available, no experimental models.

Sarma's work is a goldmine of well-researched historical information, of sound judgements, of references to primary sources (especially in Sanskrit and Persian), on the history of science in India and of references to specimens of Indian scientific instruments in India and abroad. And as I have briefly indicated here, Sarma's work is of direct importance for the 'Divergence' discussion. In short: it is a must for all historians of Indian science and for anyone interested in the global history of science and in the circulation of knowledge in pre-modern Eurasia.

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Figure 1, above
The *perpetuum mobile* according to Brahmagupta (after AE, p. 65).

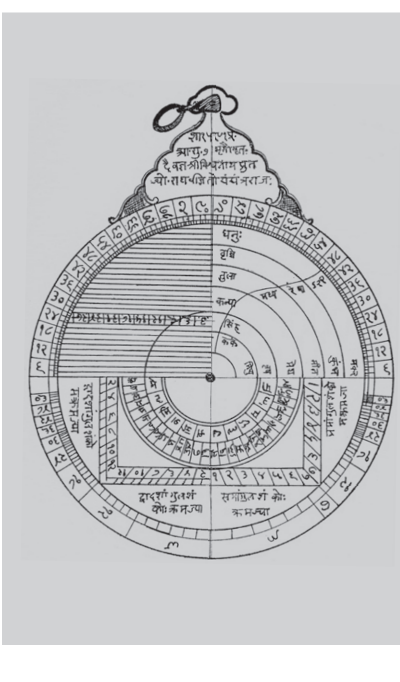

Figure 2, below left
Drawing of Sanskrit astrolabe manufactured in 1688 (after AE, p. 253).

Figure 3, below right
"Astrologers explaining the horoscope to the king" with water clock (sinking bowl type) and ring dial in front (from the Akbarnâma, © The British Library Board. (Ms. Or. 12988, folio 20b); AE p. 111)