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PERPETUAL MOTION MACHINES AND THEIR DESIGN IN ANCIENT INDIA

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PERPETUAL MOTION MACHINES AND THEIR DESIGN IN ANCIENT INDIA

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SUMMARY — The American historian Lynn White Jr. avers that the perpetual motion machines designed by Bhāskara in the twelfth century were instantly accepted by the Islamic World and then transmitted to Europe, where people like Villard de Honnecourt, in their quest for energy, received this notion with great interest and tried to apply it for the benefit of mankind. Thus, concludes White, were laid the foundations for the power technology of the modern world.

Lynn White's thesis was generally accepted by historians of technology, but his attempt to trace the origin of the perpetual motion machine to twelfth-century India was contested by al-Hassan and Needham, the former contending that such machines were known to the Arabs before Bhāskara's time and the latter claiming that both the Indian and Arabic accounts owe their inspiration to China.

This paper argues that the idea of perpetual motion is much older in India than Bhāskara's time and that the philosophical notion was translated into a design for a mechanical instrument by Brahmagupta in the early seventh century. Brahmagupta's writings on astronomy and mathematics, together with a number of scientific instruments or instrument-designs, were transmitted to the Islamic World in the eighth century and these may have included the design for the perpetual motion machines as well.

Histories of technology are perforce Euro-centred, not so much because of racial prejudice but owing to the paucity of the detailed spadework that needs to precede the writing of a comprehensive account of technologies outside Europe. Joseph Needham's monumental effort in unravelling the *Science and Civilization in China* forms an exception to this state of affairs. Significant likewise are also the studies on medieval technology by Lynn White Jr., who invites attention to the concepts

and inventions of other Asian nations. Notable in this connection is his seminal essay *Tibet, India, and Malaya as Sources of Western Medieval Technology*, published some thirty years ago.[1] One of the concepts whose origin he attributes to India is the perpetual motion machine. For students of history of technology in India it will be instructive, both conceptually and methodologically, to take a closer look at Lynn White's thesis and the controversy it engendered.

A perpetual motion machine (Latin *perpetuum mobile*, Sanskrit *ajasra-yantra*) 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.[2] Modern science says that it is impossible to construct such machines and ridicules the attempts as mere flights of fantasy. Lynn White, however, argues that such fantasies

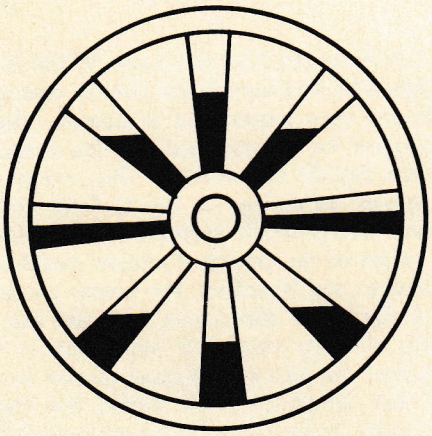

Fig. 1 - Perpetual motion wheel according to Brahmagupta.

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[1] L. WHITE JR., *Tibet, India, and Malaya as Sources of Western Medieval Technology*, «American Historical Review», LXV, 1960, pp. 515-526; reprinted in ID., *Medieval Religion and Technology. Collected Essays*, Berkeley, 1978, pp. 43-57. See also, ID., *Medieval Technology and Social Change*, London, 1964, pp. 129-131.

[2] In India, Sawai Jai Singh is reported to have invested a fortune in constructing one. Father Andreas Strobl, the Bavarian Jesuit astronomer who was at Jai Singh's court in the 1740s, reports in a letter dated 18 October 1743 that at the time of his death Jai Singh was busy erecting a machine which he had invented to demonstrate perpetual motion and that he had already spent 50,000 guilders on this venture. Cf. S. NOTI, *Land und Volk des koeniglichen Astronomen Dschaisingh II Maharadscha von Dscahaipur*, Berlin, 1911, p. 98.

are also important in the history of ideas and that the concept of perpetual motion was a significant element in Europe's thinking about mechanical power.

White traces the origin of the perpetual motion machine to twelfth-century India; in particular to Bhāskara, the great mathematician and astronomer, who in his *Siddhāntaśiromaṇi* (A.D. 1150) describes two wheels which are supposed to turn for ever. In the first model (Fig. 2) the hollow spokes are half filled with mercury and in the second (Fig. 3) a narrow channel is scooped out in the rim and filled half with mercury and half with water. According to White, these two models were immediately taken up by the Islamic world and amplified. The amplifications can be seen in an anonymous Arabic manuscript which contains the designs for six perpetual motion wheels, and one of these (Fig. 4) closely resembles Bhāskara's first model with mercury-filled spokes.[3] The Islamic world in turn transmitted the idea to the West at the beginning of the thirteenth century, together with Indian numerals and the decimal place-value system.

Europe responded to this idea of *perpetuum mobile* with great enthusiasm, engineers like Villard de Honnecourt and Peter of Maricourt designing several new models. Two of the six wheels found in the Arabic

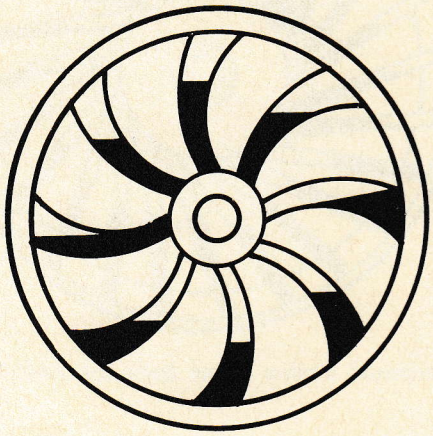

Fig. 2 - Bhāskara's first model of perpetual motion wheel.

[3] The resemblance was first noticed by H. SCHMELLER, *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern*, Erlangen, 1922, pp. 16-19.

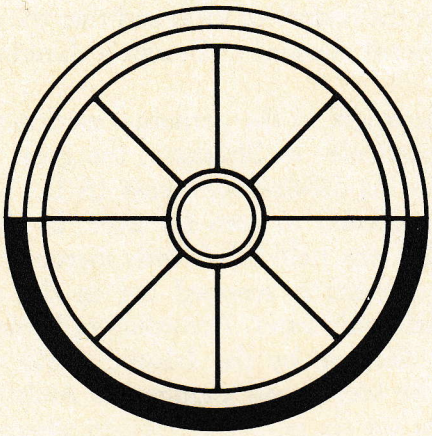

Fig. 3 - Bhāskara's second model of perpetual motion wheel.

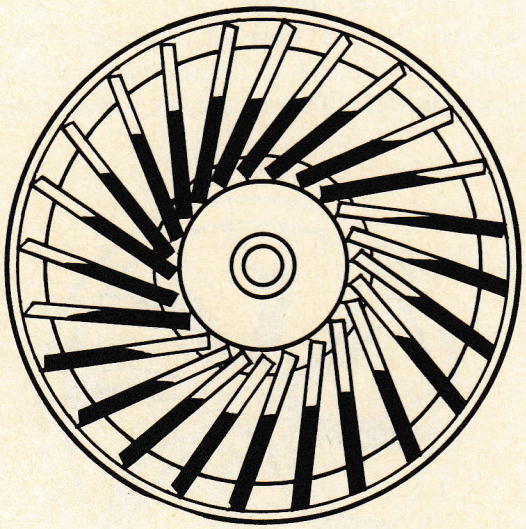

Fig. 4 - Perpetual motion wheel from the Arabic manuscript.

manuscript reappear in Villard's notebooks and Bhāskara's second model does so in an anonymous Latin work of the late fourteenth century. In contrast to India and the Islamic world, the medieval engineers of Europe tried to apply the idea of perpetual motion for practical purposes, for the material benefit of mankind. Already the industrial application

of water- and wind-power was revolutionizing manufacture, and the two new forces introduced by the Islamic world, viz. gravity and magnetism, appeared to operate with a constancy unrivalled by wind or water. Lynn White describes the quest for energy by these thirteenth-century European engineers thus:

> They were coming to think of the cosmos as a vast reservoir of energies to be tapped and used according to human intentions. They were power-conscious to the point of fantasy. But without such fantasy, such soaring imagination, the power technology of the Western world would not have been developed.[4]

He concludes his thesis by saying:

> Thus the Indian idea of perpetual motion [...] not only helped European engineers to generalize their concept of mechanical power, but also provoked a process of thinking by analogy that profoundly influenced Western scientific views.[5]

Lynn White's thesis that the foundations of modern power technology lay in the idea of perpetual motion was generally accepted by historians of technology,[6] but his attempt to trace the origin of perpetual motion machines to twelfth-century India was 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. Ahmad Y. Al-Hassan and Donald R. Hill argue in their excellent book *Islamic Technology: An Illustrated History* thus:

> In India about A.D. 1150 Bhāskara described a perpetual motion wheel which resembles one of the six such wheels in the Arabic manuscripts, but the original Arabic text is of an earlier date. The Arabic technical descriptions, the illustrations, and the whole complex of the sixteen machines are quite elaborate and, as we have seen, constitute a single approach. The occurrence, therefore, of one or two perpetual-motion wheels in the Indian text does not

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[4] L. White Jr., *Medieval Technology*, cit., p. 134.

[5] Id., *Medieval Religion*, cit., pp. 56-57.

[6] J. Needham, *Science and Civilization in China*, vol. IV, part 2, Cambridge, 1965, p. 54: «Lynn White has done a good service by pointing out that in correct historical perspective, the idea of perpetual motion has heuristic value». See also J. Gimpel, *The Medieval Machine. The Industrial Revolution of the Middle Ages*, Aldershof, 1988², pp. 127-129; R. Lannoy, *The Speaking Tree. A Study of Indian Culture and Society*, London, 1971, pp. 290-293.

imply a case of transmission from one culture to another, though there was an important transmission to the West.[7]

The authors have this to say about the original Arabic text:

> It must have been copied from an original treatise which is at present unknown to us. We can tell, however, that this original was written between the third and sixth centuries AH (ninth to twelfth centuries A.D.).[8]

Even though they are rather vague about the original Arabic text, it will be shown presently that the Indian concept of the *perpetuum mobile* is much older than Bhāskara and also older than the alleged antiquity of the «unknown and undated» original Arabic text.

The second party of opposition to Lynn White's view is represented by Joseph Needham, who asserts that

> Indeed one begins to entertain the belief that the stimulus for the flood of ideas on the perpetual motion devices may have been derived from Indian monks or Arabic merchants standing before a clock tower such as that of Su Sung and marvelling at its regular action.[9]

Lynn White dismissed this suggestion as lacking in any evidence.[10]

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*,[11] while Needham's comments emanate from his perusal of Ebenezer Burgess's rendering of the *Sūryasiddhānta*.[12] The passage cited by Needham does not even discuss the *perpetuum mobile*. No doubt, Lynn White's conclusions are highly

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[7] A. Y. Al-Hassan, D. R. Hill, *Islamic Technology. An Illustrated History*, Cambridge-Paris, 1985, p. 71.

[8] *Ibid.*, p. 70.

[9] J. Needam, *op. cit.*, p. 540.

[10] L. White Jr., *Medieval Religion*, cit., p. 53, n. 60 (= Id., *Medieval Technology*, cit., p. 130, n.3).

[11] For the text, see Bhāskara, *Siddhāntaśiromaṇi*, ed., by Bapu Deva Sastri, rev. by Ganpati Deva Sastri, Benares, 1920, Golādhyāya, Yantrādhyāya, vv. 50-53.

[12] For the text, see *The Súryasiddhánta*, with the Exposition of Ranganátha, the Gúdhárthaprakáśika, ed. by F. Hall, reprint, Amsterdam, 1974, 13.16-18.

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, a study of the original texts not only upholds Lynn White's view but even strengthens it further. Before we discuss the evidence of the Sanskrit sources, one distinction has to be made.

The Sanskrit astronomical texts describe two kinds of automatic devices, both called *svayaṃvaha-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. This teaching instrument was described for the first time by Āryabhaṭa about the beginning of the sixth century A.D.[13] This apparatus is naturally dependent on human agency to replenish the water regularly. The second variety is the *perpetuum mobile* that is supposed to turn for ever without any external help. Same Sanskrit texts designate this one as *ajasra-yantra* «perpetual machine» and it is with this variety that we are concerned here.[14]

This device was described for the first time, not by Bhāskara in the middle of the twelfth century as Lynn White supposed but more than half a millennium before him, by Brahmagupta, another great mathematician and astronomer. His *Brāhmasphuṭasiddhānta*, completed in 628 A.D., contains the first systematic treatment of the construction and use of a large number of scientific instruments.[15] Here Brahmagupta describes the *perpetuum mobile* thus (Fig. 1):

> 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 mercury runs upwards [in some] hollow spaces and downwards [in some others, as a result of which] the wheel rotates automatically for ever.[16]

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[13] S. R. SARMA, *Astronomical Instruments in Brahmagupta's Brāhmasphuṭasiddhānta*, «Indian Historical Review», XIII, 1986-87, pp. 63-74, esp. 69-71.

[14] BHĀSKARA, *Siddhāntaśiromaṇi*, Golādhyāya, Yantrādhyāya, v. 57, declares that the former are rustic (*grāmya*) contraptions as they require the help of human agency, while the real ingenuity (*yukti*) lies in the latter variety.

[15] S. R. SARMA, *op. cit.*

[16] BRAHMAGUPTA, *Brāhmasphuṭasiddhānta*, ed. by Sudhakara Dvivedi, Benares, 1902, 22.53-54:

laghudārumayaṃ cakraṃ samasuṣirārāntaraṃ pṛthag arāṇām /

What is the purpose of this wheel in the midst of instruments meant for measuring fractions of the day time or the solar or stellar altitudes? In Indian philosophical thinking, time is conceived in two ways: *khaṇḍa-kāla*, measurable time, and *akhaṇḍa-kāla*, immeasurable, eternal and cyclical Time.[17] While the other instruments are meant to measure the *khaṇḍa-kāla*, Brahmagupta obviously wishes to demonstrate the eternal and cyclical flow of the *akhaṇḍa-kāla* through his quicksilver wheel which, he believes, turns for ever and ever.

Lynn White and Needham note that this concept is quite in consonance with the «Hindu concept of cyclical and self-renewing nature of all things»,[18] or with the concept of «*kalpas* and *mahakalpas* succeeding one another in self-sufficient and unvarying round».[19] But between the philosophical notion of the eternally moving cyclical Time on the one hand and the technical design for the perpetual motion wheel on the other, there is a crucial intermediate step which needs to be emphasized. This step is represented by the concept of the universe as a perpetually turning wheel. There are abundant examples in Indian thought to illustrate this concept. The *Bhagavadgītā* (18.61), for instance, states that the Lord causes all things to revolve as though they are mounted on a wheel. Buddhism conceives the regulating principle of the universe as a wheel (*dhamma-cakka*) which, when once set in motion by the Buddha, goes on and on. It is this concept of the universe as an eternally rotating wheel that inspired Brahmagupta to design the quicksilver wheel which, in the words of Richard Lannoy, «is a uniquely Indian product of the aesthetically oriented creative imagination which seeks to harness and balance the forces of nature».[20] But it has larger historical consequences as well.

It may be recalled that Lynn White asserts that Bhāskara's mercury wheels were instantly picked up by the Islamic world, and that Al-Hassan and Hill counter this by saying that the original Arabic work on these wheels predates Bhāskara. In fact, Lynn White's linkage has

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ardhe rasena pūrṇe paridhau saṃśliṣṭakṛtasandhiḥ //
tiryak kīlo madhye dvyādhārastho 'sya pārado bhramati /
chidrāṇy ūrdhvam adho 'taś cakram ajasraṃ svayaṃ bhramati //

[17] See, for example, *Sūryasiddhānta* 1.10.

[18] L. WHITE JR., *Medieval Technology*, cit., p. 130.

[19] J. NEEDHAM, *op. cit.*, p. 540.

[20] R. LANNOY, *op. cit.*, pp. 291-292.

no foundation because Bhāskara's work is not known to have been translated into Arabic or otherwise transmitted to the Islamic World.

On the other hand, it is quite well known that Brahmagupta's works were so transmitted in the second half of the eighth century.[21] Under the Caliphate of al-Mansur (754-775), there was a great flow of scientific ideas from India to Baghdad. The astronomical works of Āryabhaṭa and Brahmagupta, Indian numerals with decimal place-value, and the like were transmitted to, and adopted by, the Islamic world. Based on the Arabic adaptations of Brahmagupta's *Brāhmasphuṭasiddhānta*, there developed the Sindhind school of astronomy. Likewise, certain basic methods of observational astronomy were also borrowed by the Arabs from India. For example, the method taught in the Sanskrit texts for determining the cardinal directions with the shadow of a gnomon came to be known among the Arabs as the «Indian circle». Mu'ayyad al-Dīn al 'Urḍī, the celebrated instrument maker at the Marāgha Observatory (established in 1259), states that the Indian circle is the best among the innumerable methods of finding the cardinal directions.[22] His technique of aligning a plane horizontally by means of water has antecedents in India.[23]

In view of these transmissions, it is quite possible that the Arabs became acquainted, in the latter half of the eighth century, with the idea of the *perpetuum mobile* as described in the *Brāhmasphuṭasiddhānta* which was available to them in Arabic. Al-Hassan and Hill, it will be recalled, assign the original Arabic text containing the descriptions of *perpetua mobilia* to a period between the ninth and the twelfth centuries, without clearly stating the reasons. Even if the earliest date, viz. ninth century, is accepted, Brahmagupta's mercury wheel reached the Arabs at least one century before that date.

Brahmagupta's mercury wheel is earlier also than Su Sung's clock tower (1090 A.D.)[24] and other Chinese devices. I-Tsing, a Buddhist traveller who came to India during Brahmagupta's life time, showed

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[21] On the transmission of Indian astronomy to the Islamic World, see F. SEZGIN, *Geschichte des Arabischen Schrifttums*, vol. VI, Leiden, 1978, pp. 116-120; M. MOHD. YOUSUF, *Influence of Indian Sciences on Muslim Culture*, «Islamic Culture», XXXVI, 1962, pp. 102-118.

[22] H. J. SEEMANN, *Die Instrumente der Sternwarte zu Marâgha nach den Mitteilungen von al 'Urḍī*, Erlangen, 1928, pp. 24-25; E. WIEDEMANN, *Ueber den indischen Kreis*, «Mitteilungen zur Geschichte der Medizin und Naturwissenschaften», XI, 1912, pp. 252-255.

[23] H. J. SEEMANN, *op. cit.*, pp. 49-50; S. R. Sarma, *op. cit.*, p. 65.

[24] J. NEEDHAM, W. LING, D. J. DE SOLLA PRICE, *Heavenly Clockwork. The Great Astronomical Clocks of Medieval China*, Cambridge, 1986[2].

great appreciation of Indian water clocks but he himself was not aware that water clocks (though of different type) were also available in China.[25] Therefore, the question of his, or an Indian monk's, imparting the knowledge of Chinese automatic clocks to Indian astronomers like Brahmagupta does not arise, contrary to what Needham would like to believe.

Thus perpetual motion machines, numerals in decimal place-value system, sine tables etc. are notable elements in a complex set of ideas that were transmitted from India to the Islamic world in the eighth century and thence to the West at about the beginning of the thirteenth century. If the idea of perpetual motion played a role in the development of mechanical power in Europe, the source then is not Bhāskara of the twelfth century but Brahmagupta of the seventh.

However, Bhāskara did make some important innovations in mercury wheels. As has been stated already, his *Siddhāntaśiromaṇi* contains the description of two mercury wheels. The first one is similar to Brahmagupta's, even in the wording of the description.[26] But Bhāskara adds that the hollow spokes should be *kiñcid vakrāḥ*. Wilkinson rendered this expression as «let them also be all placed at an angle somewhat verging from the perpendicular»,[27] and this translation led Lynn White to conclude that the spokes are slanted as in one of the wheels (Fig. 4) of the Arabic manuscript.

In his commentary, Bhāskara himself explains that *kiñcid vakrāḥ* means that the spokes should be slightly curved, all towards the same direction like the petals of the *nandyāvarta* flower (*Tabernamontana coronaria*) (Fig. 2). Because of such curvature, Bhāskara goes on to explain, the mercury in one part of the wheel runs fast towards the bottom of the spokes while in another part it runs towards the top of the spokes. Impelled by this internal movement, the wheel itself turns automatically and will continue to do so.[28]

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[25] I-Tsing, *A Record of the Buddhist Religion as Practised in India and the Malay Archipelago*, Engl. trans. J. Takakusu, reprint. Delhi, 1966, p. 146; S. R. Sarma, *Water Clocks and Time Measurement in India*, forthcoming.

[26] Bhāskara, *Siddhāntaśiromaṇi*, Golādhyāya, Yantrādhyāya, vv., 50-51ab:

laghudārujasamacakre samasuṣirārāḥ samāntarā nemyām /
kiñcid vakrā yojyāḥ suṣirasyārdhe pṛthak tāsām //
rasapūrṇe tac cakraṃ dvyādhārākṣasthitaṃ svayaṃ bhramati //

[27] As quoted by L. White Jr., *Medieval Technology*, cit., p. 130.

[28] Bhāskara, *Siddhāntaśiromaṇi*, p. 248: *tāś ca nandyāvartavad ekata eva sarvāḥ kiñcid vakrā yojyāḥ / ...atra yuktiḥ / yantraikabhāge raso hy ārāmūlaṃ pravisāti / anyabhāge tv ārāgraṃ dhāvati / tenākṛṣṭaṃ tat svayaṃ bhramatīti /*

Besides thus modifying Brahmagupta's wheel, Bhāskara designed another variant in which a narrow channel is cut in the surface of the rim and filled half with mercury and half with water and then sealed up (Fig. 3). The water, trying to flow downwards, pushes the mercury and vice versa, this internal tension resulting in the rotation of the wheel itself.[29]

The last word on automata was uttered in India by Raṅganātha who, writing in 1603, observed that the Europeans were great experts in the science of automata.[30] He belonged to an influential family of astrologers with connections at the Mughal court and may have seen or heard of the automatic clocks and watches brought by Europeans as gifts to the Mughal court. He did not, however, realize that the first model of an automatically turning device was designed in India itself about a thousand years before him by the astronomer Brahmagupta.

This brings us to the end of the story of the *perpetuum mobile* and its Indian origin. In today's world of narrow loyalties, one is accustomed to ask to whom the credit should go: is it due to Brahmagupta for the origin of the idea, or to the Islamic world for its elaboration and spread, or to the Occident for its practical application? Lynn White, quite rightly, sees these three kinds of endeavour as complementary to one another, when he says that

> it is an objective fact that, despite difficult communication, mankind in the Old World at least has long lived in a more unified realm of discourse than we have been prepared to admit.[31]

We may conclude by saying that when an anonymous painter in Europe depicts the Almighty God as an architect-engineer holding the

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[29] *Ibid.*, Golādhyāya, Yantrādhyāya, vv. 51cd-53ab:

utkīrya nemim athavā parito madanena saṃlagnam //
tadupari tāladalādyaṃ kṛtvā suṣire rasaṃ kṣipet tāvat /
yāvad rasaikapārśve kṣiptajalaṃ nānyato yāti //
pihitacchidraṃ tad ataś cakraṃ bhramati svayaṃ jalākṛṣṭam /

This is followed by the description of another *perpetuum mobile* (vv. 53cd-56) in which the rim of the wheel is equipped with a series of pots which are successively filled with water from an overhead reservoir through a siphon, the full pots moving downwards and causing the wheel to turn. This cannot be really termed a perpetual wheel, as the reservoir has to be refilled. But this wheel is somewhat reminiscent of Su Sung's clock tower. Cf. S. R. Sarma, *Astronomical Instruments in Brahmagupta's Brāhmasphutasiddhanta*, cit., p. 74.

[30] In his commentary on *Sūryasiddhānta* 13.22, p. 365; cf. S. R. Sarma, *Astronomical Instruments...*, cit., p. 74

[31] L. White Jr., *Medieval Religion*, cit., p. 57.

globe of earth in one hand and a pair of compasses in the other,[32] or when Bhoja, King of Dhārā, conceives God as creating the universe in the form of a perpetual motion wheel,[33] they too seem to share a unified realm of vision.

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[32] The painting is preserved in the Nationalbibliothek, Vienna, and reproduced in J. GIMPEL, *op. cit.*, p. 145.

[33] *Samarāṅgaṇasūtradhāra*, ed. by T. Gaṇapatiśastrī, rev. by V. S. Agrawala, (GOS 25), Baroda, 1966, 31.1:

bhrāmyad-dineśa-śaśi-maṇḍala-cakra-śastam
etaj jagat-tritaya-yantram alakṣyamadhyam |
bhūtāni bījam akhilāny api saṃprakalpya
yaḥ santataṃ bhramayati smarajit sa vo 'vyāt ||

«He conceived the three worlds as a mechanical wheel,
Its rim he fashioned from the orbits of the sun and the moon.
The nave is hidden, but the creatures provide the motive power.
Having crafted this world-machine,
He lets it rotate for ever and ever.
May that Śiva, the passion's conqueror, protect you».