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Monthly Newsletter of Vigyan Prasar

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VP News

Inside

Vigyan Prasar in Tripura

North Eastern states are to some extent geographically isolated from the other states of our country. And Tripura is the most isolated state among the seven sisters of the North Eastern. In spite of this isolation, people of Tripura are out getting information and news at the right time in so far as science popularisation activities in the country are concerned. Perhaps it is the deep interest of the people of Tripura in science popularisation activities which is reflected in their active participation in the National Children's Science Congress and similar other activities. To keep this interest alive and to consolidate it and deepen it further, Vigyan Prasar has given a Fellowship to Shri Sanjay Banerjee of Tripura — a science activist working in the field of science popularisation for the last twenty five years. This has resulted in several positive developments : initiatives have been taken to increase school science club activities in different parts of the state by forming new and/or reviving existing science clubs in schools. As a result, applications for membership of VIPNET are regularly coming in from different parts of the state.

A VIPNET member club, Kishan Bijnan Chakra, organised (in association with Vigyan Prasar) a workshop aimed at enhancing science coverage in the mass media . It called for inputs to media organisation for the purpose. Vigyan Prasar has started providing science articles and science news items to newspapers and radio. Plans are being drawn up to produce joint programmes with Doordarshan Kendra, Agartala.

Expert from the Department of Health & Family Welfare, Government of Tripura, addressing the children of VIPNET Science Club, Birendranagar (Tripura), on the occasion of the National Environment Awareness Campaign.

Total Solar Eclipse

The Indian Air Force has agreed to join hands with Vigyan Prasar—an autonomous organisation under the Department of Science & Technology, Government of India, for video-filming the Total Solar Eclipse (TSE) on August 11, 1999. Thus even if monsoon clouds obscure the view of the eclipse on the ground, IAF planes flying above the clouds will be able to capture the rare event. For this Video-filming mission, Vigyan Prasar has arranged Camera teams of two each from Doordarshan, Electronic Media Production Centre(EMPC) of IGNOU, and Central Institute of Education Technology(CIET) of NCERT, besides its own team to fly aboard an AN -32 aircraft of IAF for this purpose. The pilot of a MiG-25 plane would also try to capture the TSE for Vigyan Prasar with a mini digital video camera, from a height of 80,000 ft.

... think scientifically, act scientifically ... think scientifically, act scientifically ... think scientifically, act ...

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FREEDOM

We are an independent country, no doubt, and have been so for over five decades now. But do Indians have all the freedoms? Freedoms, which people in several of the countries (that we would like to compare overselves with) have! And does India, as a nation, have freedoms that some of the other countries appear to possess and exercise? This Independence Day (August 15) let us try looking at answers to these questions and ponder over them.

Indians don't have many freedoms enjoyed by citizens in other countries: like freedom from large scale illiteracy and poverty, from harassment at the hands of providers of utilities (like electricity, water, cooking gas, phones etc), traffic police, law enforcement agencies, tax collectors and so on; freedom from widespread corruption encountered in trying to secure ration cards, drivers' licences, railway reservation, cinema tickets etc; freedom from large-scale exploitation by taxi pliers, and while performing a variety of other daily chores. Many more examples can be added to the foregoing list.

The above, unfortunately, is only half of the story. For, Indians in India enjoy so many other freedoms and exercise so many liberties which people in other countries could not even dream of: freedom from following or adhering to any rules and regulations (including those relating to traffic safety, fire safety, handling of hazardous substances, explosives, toxic chemicals and so on), freedom from keeping their surroundings clean and tidy; freedom of spitting, urinating and throwing of litter anywhere and everywhere; freedom of coming later and going earlier than the opening and closing hours at their places of work; freedom of drawing full salaries from the government without doing full quota of work; and so on and on.

Let us next look at freedoms India has and those it would appear not to have. As an independent, sovereign nation of the world, and a member in good standing of the United Nations (unlike ones who have not regularly paid their membership dues and owe huge amounts as arrears), India, in principle, ought to have as much freedom or as many freedoms as any other country does!

As an independent nation India ought to have the freedom to take/make its own decisions concerning things such as: the kind of science and technology she should or would develop; technologies, products and services it should or should not sell to (or buy from) other countries; assess her own security needs and requirements, and take whatever steps it deems appropriate to fulfill the same; to take adequate steps to neutralize and liquidate any threats to its security and territorial integrity; the nature and extent of globalization and liberalization that is appropriate for its economy; what sectors of her economy should or should not be thrown open to outsiders; how much of her GDP to spend on defence, on science & technology, or on research and development work; and so on and so forth.

But does India have all the above-stated freedoms? In principle, yes in many cases. In practice, India's freedom in some cases gets diluted by counterpulls and pressures, generated by her own weaknesses (economic and military) or by her crucial dependence on outside credit, technology, hardware, etc for several of her essential needs. It is quite clear that as a nation India can actually exercise any freedom as long as doing so does not in any way conflict with the economic, political, military or trade related interests of any of the big-brother nations – as they see them – or, else if it does, she ought to be ready and able to face their wrath and accompanying consequences. Put in another way, if India as a nation wishes to exercise all its freedoms and do so when it deems fit, it has to become self-reliant, even self-sufficient in crucial areas, and strong and powerful enough economically and militarily to neutralize or effectively liquidate any threats to its sovereignty, territorial integrity and economic interests worldwide. We shall be able to choose only when we cease all begging directly or indirectly.

This August 15th, let's ponder over the above and think hard about how we can make India truly independent, capable of exercising all freedoms that a self-respecting sovereign country of our size, our past and our stature ought to possess.

Among other things, we Indian citizens in India would need to forego most of the freedoms (mentioned in an earlier para) we have been exercising with impunity and work hard to gain some others which we don't possess at present — freedom from large-scale illiteracy, poverty and hunger (the latter, despite overflowing buffer grain stocks)!

Unless we begin doing things differently – with self-discipline, dedicated hard and meticulous work, giving off our best for our country – we would be discussing this subject once again, come August 15 next year and ditto thereafter!

We would not want to do that. Would we? Readers' views are solicited.

❑ NKS

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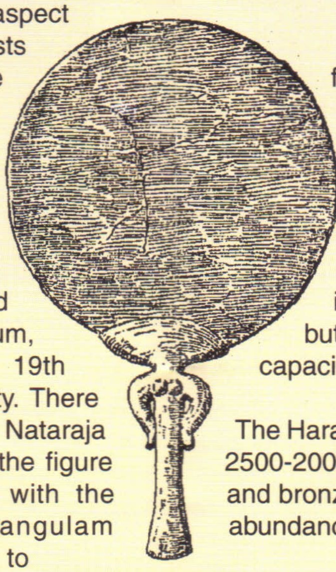
DANCING GIRL FROM MOHENJO-DARO

The National Museum in New Delhi is one of the richest storehouses of India's cultural and scientific heritage. Among the prehistoric and protohistoric objects displayed in the very first gallery in the Museum's ground floor, there is a bronze figure from Mohenjo-daro (now in Pakistan). Made in *circa* 2500 B.C., it is an image of a naked young girl in a dancing pose. Though the figure's height is only 10.8 cm., it tells us a lot about the metal technology that was developed in the Indus Valley Civilization, also called the Harappan Culture.

The bronze Dancing Girl from Mohenjo-daro is the most outstanding item among the objects displayed in the gallery. It is the first sculpture in dancing gesture discovered in the Indian subcontinent. It is also one of the earliest cast bronzes in this cultural area. But its most interesting aspect is that in casting it the Harappan metallurgists used an advanced technique known as the lost-wax (*cire perdue*) process.

The Harappan tradition of bronze casting, so well begun, did not continue unabated. The art of producing bronze sculptures emerged again during the Kushan period. The collection of bronze and metallic sculptures in the National Museum, covering the period from the 6th to the 19th centuries, is very rich in variety and quality. There are a large number of bronze images of Nataraja Shiva, one of the best among them being the figure in the pose of *Chaturatandava,* that is with the legs forming a square, from Tiruvarangulam (Pudukkottai District, Tamilnadu). Belonging to early Chola period (*circa* 975 A.D.), the 71.5 cm. high bronze image is one among the outstanding sculptures in the possession of the Museum.



Copper Mirror
from Mehi (Baluchistan)

There is a vast gap of time and space between the Dancing Girl from Mohenjo-daro and the *Chaturatandava* Shiva from Tiruvarangulam. The bronze girl was cast in north-west India around *circa* 2500 B.C. The Chaturatandava Shiva was created in south India in the 10th century A.D. There is a gap of some 3500 years between the two. But there are some similarities also. One is *Nartaki*, a dancing girl, possibly a professional *Devadasi*. The other is *Nataraja*, the Lord of dance and music. The features of the unclad body of the dancing girl show her to be that of the Proto-Australoid type which, perhaps, constituted a segment of the mixed Harappan society. The concept of Proto-Shiva also appears to be the contribution of the Indus Valley Civilization.

The most important similarity between the two bronze images is the technique employed in their casting. In ancient Sanskrit treatises like *Manasara* and *Manasollasa* the method is described as *Madhuchchhishtavidhana* or the lost-wax mode (the French word for it is *cire perdue*).

The lost-wax process is an elaborate one. To cast a small solid (*ghana*) statue, such as the dancing girl, it was first modelled in wax. The wax model was then covered with a layer of fine clay and after this was added a thick outer coating of coarse clay. The mould was first allowed to dry and then heated so that the wax could melt and run out. Molten metal could then be poured into the hollow of the hard mould thus prepared. The mould had to be broken open to get the object cast.

To cast a hollow (*sushira*) bronze statue, first a clay core was made and allowed to dry. On it was then prepared the model in wax the thickness of which depended on the thickness of the metal required. Rest of the process was as above. To prevent the shifting of the inner core thin rods were inserted to attach it to the outer mould. This technique of lost-wax casting is not much different from that followed today, but to cast large single statues was beyond the capacity of the Harappan craftsman.

The Harappan civilization, which flourished during *circa* 2500-2000 B.C., had produced a large number of copper and bronze objects. It appears that there was a sudden abundance of metal in the Indus culture. The Harappans were, right from the start, well acquainted with not only copper metallurgy but also bronze technology. But this technology could not have been realised all of a sudden. The beginning was made with native copper available in small quantities in the form of nuggets , which could be shaped by hammering and also beaten out into sheets. Then it was discovered that, when heated, copper becomes plastic, even liquid, and can take the shape of any container into which it is poured. Copper melts at 1083^{0}C.

But native copper was scarce. Man had to learn to extract copper from its ore. Fortunately, some copper ores, because of their bright colours, were already known. For example, the green coloured malachite [$CuCO_3.Cu(OH)_2$] was used as eye-paint in ancient Egypt. It is also the most easily reduced ore of copper. But reduction or smelting is a complex process and therefore must have originated only at a few centres of the Ancient World.

Dancing Girl from Mohenjo-daro
(National Museum, New Delhi)

Chaturatandava Shiva from Tiruvarangulam
(National Museum, New Delhi)

The next stages are alloying and casting. When copper is alloyed with tin, lead, arsenic etc. casting is easier and the product obtained is superior. A good quality bronze is obtained by alloying copper with 8 to 11 per cent tin. In the bronze objects from Mohenjo-daro the presence of tin is 4.5 to 13 per cent. Surely, the mixing was deliberately done to obtain suitable bronzes. The Harappan metallurgists were able to work not only with open moulds but, as we have seen, also with the advanced and complex lost-wax process. Most of the Harappan tools are simple. But their razors, chisels, arrowheads and fishhooks are among the best in the Ancient World. They had also made the true saw and were using tubular drills for making fine steatite beads.

How did the Harappans happen to achieve this metal prosperity and technological status? It is rather a difficult question to answer, because the pre-Harappan developments of copper-bronze metallurgy are not sufficiently clear. The mountain region extending from Anatolia to Afghanistan is rich in copper ores, more so its eastern side. Presently the site Tal-i-Iblis near the Kerman range in south-east Iran is regarded as the earliest known centre of copper metallurgy. The smelting equipment discovered from this site is datable to *circa* 4500 B.C. From here the knowledge is believed to have spread to the west and the east. Towards the east Mundigak in Afghanistan and some pre-Harappan sites from Baluchistan provide evidence of copper and bronze metallurgy.

The pre-Harappan (*circa* 3500-2300 B.C.) sites (Nal, Kulli, Mehi etc.) discovered in Baluchistan are rich in copper and bronze objects. The Mehi cemetery among its grave-goods has yielded a unique copper mirror 12.7 cm in diameter, having a copper handle representing a female figure with breasts and arms akimbo; the head is provided by the reflection of the mirrror's user! There is nothing like the Mehi mirror in the contemporary Western Asia, nor in the later more advanced Harappan culture. This shows that the Baluchi metal-smiths of the period were well-acquainted with copper-bronze metallurgy.

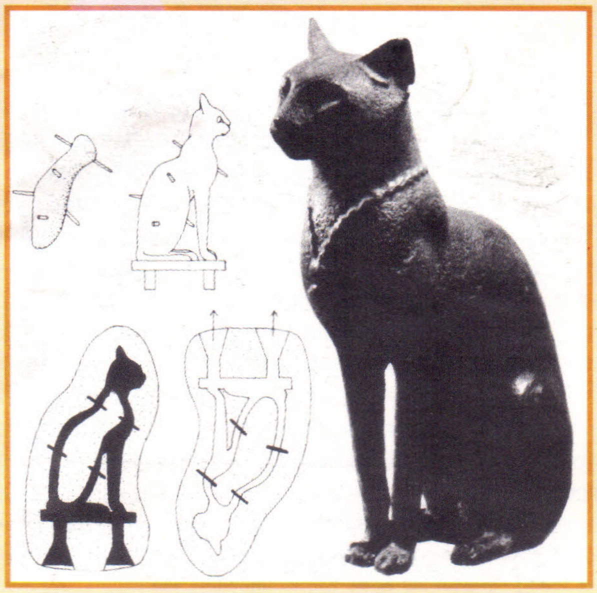
In the Harappan culture it is a full-fledged technology. What were its sources of copper? Baluchistan, Afghanistan, Oman, Rajasthan and Bihar all have copper mines. But it could not have been possible for the Harappans to exploit the distant mines, such as that of Bihar. Analyses of copper-bronze objects and ores from several mines suggest that the Harappans must have obtained much of their copper from the Khetri mines of Rajasthan. In addition to this source, the mines in Baluchistan and Afghanistan might have been also tapped by the Harappans. Tin, a scarce metal, must have been imported from Baluchistan and eastern Iran. The more than 200 Harappan artifacts that have been analysed show that only 23% were alloyed with tin, 12% with arsenic and 8% with lead.

The advent of metal was a revolutionary event in the history of mankind. Though stone tools were still in use in the Harappan culture, it was the metal that gave momentum to its socio-economic development. Metallurgy increased production, gave rise to several specialised crafts and also revealed some chemical and physical laws. Metallurgy must have also played a prominent role in the advancement of urbanization.

The Indus Civilization had several urban centres. For the evolution of an urban society the primary requirement was the agricultural surplus. The soft alluvial soil of the Indus plains was capable of providing such surplus. What was needed was better tools for agriculture such as the metal ploughshare. Thus , when new mines were tapped and metal became abundant the Harappan society began to progress rapidly. All this led to the need of planned cities. That is why right from the beginning the Indus cities were pre-planned.

Metallurgy is a full-time specialist's job. We have evidence of sixteen copper furnaces from Harappa, a number of copper workshops in Lothal and large quantities of copper oxide ore from a brick-lined pit at Mohenjo-daro. All this suggests that copper technology was a developed craft in the Indus Civilization. The operations of mining, smelting and casting are so elaborate that normally it is not possible to find time to work in the fields or look after cattle. Thus, withdrawn from direct food production, the Harappan metal-workers must have formed an independent class of their own. The class of priests was most probably the first one to depend on agricultural surplus. The next class to join the rank was that of the craftsmen, including the metallurgists. In the Harappan society the metallurgists most probably held a privileged position.

The climax of the Harappan metal technology can be observed in the four exquisite bronzes obtained from Daimabad (Ahmednagar district, Maharashtra) and now preserved in the National Museum. Assigned to the late Harappan Chalcolithic times (2000-1800 B.C.), they consist of a chariot yoked to a pair of bullocks driven by a naked man, an elephant, a rhinoceros and a buffalo. They stand nearly 28 cm high and all together weigh about 65 kg. This hoard has not been thoroughly studied as yet.



Stages of lost-wax (*cire perdue*) technique of hollow casting

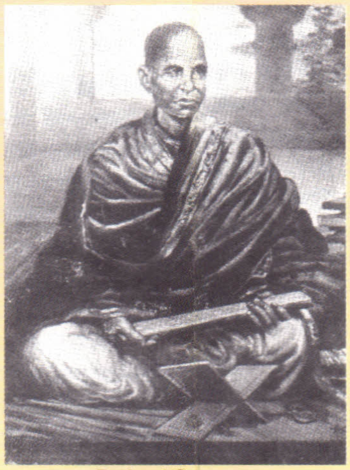
With the decline of the Harappans the bronze technology developed by them also came to a close. The copper artifacts of the post-Harappan Chalcolithic cultures (second millennium B.C.) of Rajasthan, Madhya Pradesh and Maharashtra show no influence on them of the Indus metallurgy. Similar is the case with the Copper hoards discovered at several places in Uttar Pradesh, Bihar and Madhya Pradesh. Datable to about 1100 B.C., they are a great puzzle for the archaeologists. The metalcraft that was developed in the first urbanised society of the Indian subcontinent has its own independent identity.

Iron objects appear in India from about 1100 B.C.

❑ Gunakar Muley

100 YEARS OF *SIDDHANTA-DARPANA*

One hundred years ago, *Siddhanta-Darpana*, a treatise on astronomy was published. Though it was written by a man, who lived throughout his life in a place amidst hills and jungles of Orissa and far away from the contemporary seats of learning or for that matter far from any educational activity, it proved to be the most important work published in India after *Siddhanta-Shiromani* (written in A.D. 1150) by Bhaskara II. The author of the book, Mahamahopadhyaya Pandit Samanta Chandra Sekhara Harichandan Mohapatra (locally and lovingly known as Pathani Samanta) observed, verified and corrected wherever necessary all that was known to astronomers of ancient India. Often he surpassed them. He discovered new phenomena and gave new formulations. He was the first Indian astronomer to notice all the three irregularities of the moon viz., evection, variation and annual equation. His achievement is amazing. In fact it would appear incredible when we take into account the fact that he had no formal education. He knew no other language except Sanskrit and his mother tongue Oriya. The open blue, starry sky was his observatory and he made all the astronomical observations without any optical assistance. He did not see a telescope till late in his life, and did not even possess a timepiece.



Pathani Samanta
(1836-1904)

The work was written in the style of our *siddhantas*. It may be noted here that by about A.D. 400 or may be even earlier a new class of astronomical works, known as *siddhantas*, emerged which attempted to present the correct solution of astronomical problems. In fact, the Sanskrit word *siddhanta* means 'final conclusion' or 'solution'. It is said that there were 18 original *siddhantas*. However, we know of only about five *siddhantas*, which were summarised by Varahamihira (born c. A.D. 505) of Avanti (modern Ujjain) in his Panchasiddhantika. These are: the *Paitamaha-siddhanta*,, the *Vasistha-siddhanta*, the *Paulisa-siddhanta*, the *Romaka-siddhanta* and the *Surya-siddhanta* (also known as *Saura-siddhanta*). The *siddhantas* have come down to us through revisions made by several authors. The *siddhantas* laid special emphasis on computations and thus opened the way to new methods of analysis.

Leading astronomers of this period were Aryabhata I (born A.D. 476), Varahamihira (6th century A.D.), Bhaskara I (born c. A.D. 600), Brahmagupta (born c. A.D. 598), and Bhaskara II (born A.D. 1114). Besides the compilation work of Varahamihira, the immortal works of this period were *Aryabhatia* (by Aryabhata I), *Brahmasphuta-Siddhanta* (by Brahmagupta) and *Siddhanta-Shiromani* (by Bhaskara II).

Pathani Samanta was born on January 11, 1836 in Khandapara, a village in western Orissa. From an early age Pathani Samanta was taught Sanskrit Grammar, *Smritis, Puranas,* Logic, Medicine and all the important *Kavyas* in original. At the age of ten his father taught him a little of astrology. As we know the determination of *lagnas* (the rising point of ecliptic) is a very frequent necessity in horoscopy and, traditionally without the knowledge of the positions of the stars — which changed night after night — astrological predictions could not be made. This led him to watch the position of the stars night after night. The idle curiosity exhibited in star-gazing developed into the habit of really fruitful study of astronomy. He had no one to guide him in his observations except the *Siddhantas* available in his family library. He undertook the systematic study of these works with the help of commentaries. By the age of 15 he mastered the rules for calculating the ephemerides (tables showing the positions of heavenly bodies at regular intervals in time) of the planets. While calculating the positions of the planets he found that neither the stars appeared on the horizon at the right moment nor could the planets be seen in the right places. He began to observe and calculate the movement of heavenly bodies night after night. At the age of 23 he began to note down systematically the results of his observations.

His grandfather was a local king (Raja of Khandapara) and the king of his time Raja Mardaraj Bhramaravara Ray was the son of his eldest cousin. However, he was ignored by the king as he did not appreciate that his uncle should do the work of star gazing which, according to him, was derogatory to his position. Thus throughout his life he remained Samanta (member of king's family) by name and did not enjoy any privilege. He had very small income — Rs. 500/- a year from a few villages, and a quantity of food grain from his tenants. With this small income he had to support a number of attendants maintained hereditarily.

Siddhanta-Darpana was originally written on palm leaves in Sanskrit (in Oriya characters). The book was first published in *Devnagari* script in 1899 from a Calcutta press with the financial support of the king of Athmallick and the king of Mayurbhanj. J. C. Ray, Professor of Physical Science, Cuttack College (today's Ravenshaw College), wrote a very illuminating introduction and also supervised its printing. The treatise contains 2,500 *shlokas* of various poetical metres. Out of the total 2,500 *shlokas* 2,284 *shlokas* were composed by Pathanai Samanta and the remaining 216 were quoted from the old *siddhantas* mainly from the *Surya Siddhanta* and the *Siddhanta-Shiromani*. In fact in writing *Siddhanta-Darpana* Pathani Samanta followed the footstep of Bhaskara -II. But he was not a blind follower of his guru. Pathani Samanta did not accept the elements of planets given by Bhaskara-II as they were not correct in his time.

The treatise was of highest literary merit. As Prof. Ray wrote "It appears to me that the metrical composition alone, apart from its value as a contribution to Hindu astronomy is such as to entitle him to a high place among the writers of Sanskrit verse of the present day." The treatise is broadly divided into two parts — *Purvardha* (first half) and *Uttarardha* (latter half). In its 24 chapters called *Prakasa* or illuminations reflects the whole gamut of *Siddhanta* calculations for exactly composing an almanac. The first part contains 15 chapters and the second part 9. Further the chapters are grouped under five sections viz., *Madhyamadhikara, Sphutadhikara, Triprasnadhikara, Goladhikara* and *Kaladhikara.* The contents of different chapters are shown in Table 1.

The journal *Knowledge* which reviewed the book in 1899 wrote:

"Of all the numerous works on astronomy that have been published within the last few years, this is by far the most extraordinary and in some respects the most instructive. It is written in Sanskrit by a Hindu of a good family of Khandapara in Orissa, and is a complete system of astronomy founded upon naked eye observations only, and these made for the most part with instruments devised and constructed by the writer himself.... To Hindus, for whom their religious observances are regulated by astronomical configurations, this work by one of themselves, a strict follower of the severest laws of their religion, and conducted throughout solely by traditional Hindu methods, is of the highest importance, as it removes the confusion which had crept into their system, without in the least drawing upon the sources of western science. But the work is of importance and interest to us westerners also. It demonstrates the degree of accuracy-which was possible in astronomical observation before the invention of the telescope, and it enables us to watch, as it were, one of the astronomers of hoary, forgotten antiquity actually at his work before us to-day."

Pathani Samanta made contributions to the following four important aspects of astronomy:

1. Observations 2. Calculation 3. Method of measurement and instrumentation 4. Theory and models.

Commenting on Pathani Samanta's achievement, the journal *Nature,* which reviewed *Siddhanta-Darpana* wrote:

"We get some notion of the success that attended the work, and of how much it is in one man's power to accomplish, if we examine the difference between the values he assigned to some of the constants of astronomy and those in use with ourselves. The error in the sidereal period of the sun is 206 seconds: of the moon, 1 second : Mercury, 79 seconds: Venus, about 2 minutes: Mars, 9 minutes: Jupiter, an hour: and Saturn, rather more than half a day. The accuracy with which he determined the inclination of the planets to the ecliptic is still more remarkable. Mercury offers the largest error, and that is only about two minutes. In the case of the Solar orbit the greatest equation to the centre is only 14 seconds in error . In the lunar theory, the revolution of the node has been concluded with an error of about 5.5 days, less than the thousandth part of the whole period: while he has independently detected and assigned very approximate values to the evection, the variation, and the annual equation."

Table 1

Name of section	Chapter number	Chapter content	Number of Slokas in the chapter
Madhyamadhikara	1	Description of time	55
	2	Description of Bhagan,etc.	25
	3	Mean planet positions	77
	4	Various corrections	57
Sphutadhikar	5	True Planet Positions	221
	6	Finer Corrections	161
Triprasnadhikara	7	Gnomons, etc.	94
	8	Lunar eclipse	87
	9	Solar eclipse	78
	10	Parilekha description	37
	11	Transit, etc., of planets	111
	12	Alignments of planets	93
	13	Risings and setting of planets	84
	14	Phases of the moon	67
	15	Description of Mahapata	70
Goladhikara	16	A set of questions	79
	17	Description of the Earth	159
	18	Description of the Earth (contd.)	175
	19	The celestial sphere	123
	20	Description of instruments	111
	21	Some deeper questions	249
Kaladhikara	22	Description of years, etc.	76
	23	Prayer to Purusottama	55
	24	Conclusion	156
Total			2500

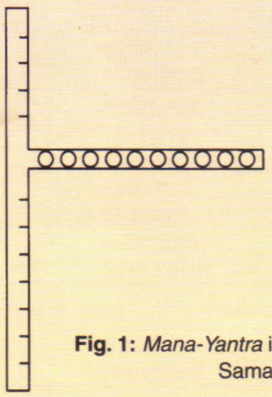


Fig. 1: *Mana-Yantra* invented by Pathani Samanta.

The sidereal positions of the Sun, Moon and the five planets and inclination of planets to the ecliptic given in *Surya Siddhanta, Siddhanta Shiromani, Siddhanta-Darpana,* the European values as known in 1899 and the modern values are shown in Tables 2 & 3.

The instruments used for his practical observation of the night sky were made by himself indigenously. His instruments which were mostly made up of wood and bamboo pieces can be broadly classified into three categories :

i. Instruments for measuring time included sun-dials, like *Chakra yantra* consisting of a calibrated wheel with an axis at the centre measured time for an entire day; *Chapa Yantra,* a calibrated wheel with an axis at the centre measured time for half of a day and *Golardha Yantra,* a hemispherical dial. He had also Swayambaha Yantra, a water clock.

ii . The versatile instruments which mainly included a Shanku or Gnomon as it is popularly known and *Mana Yantra.* The *shanku* consisted of a stick of measured height fixed vertically on a levelled ground. By measuring the shadow length of the stick cast by the sun one could measure the local time, the altitude, zenith distance and declination of the sun, its position in the Zodiac, latitude and direction of a place and many other things.

Mana-Yantra (measuring instrument) essentially a tangent staff, was invented by himself. It consisted of a thin rod of wood at one end of which is fixed another rod at right angles in the form of a T (Fig. 1) with unequal horizontal arms. Careful use of the device can give both height and distance of the mountains and other distant objects. The instrument is described in detail in *Siddhanta Darpana.* Holes are drilled in to the vertical side at the measured distances. All the three arms are calibrated.

III. Amillary Sphere or *Gola Yantra,* widely used by ancient astronomers of India for determining the position and motion of planets and as a demonstration kit for showing to the students various great circles used in astronomy, was improved by Pathani Samanta. With this improved version he could measure the longitude and declination of planets.

In his introduction to *Siddhanta Darpana* Prof. J.C. Ray has drawn a number of parallels between Tycho Brahe (A.D. 1546-1601) and Pathani Samanta. Tycho Brahe made accurate astronomical instruments and used them to make observations enabling him to revise the existing, often inaccurate, astronomical tables. Tycho Brahe rejected the Copernican

Table 2: Sidereal Periods in mean solar days

	Surya Siddhanta	Siddhanta Shiromani	Siddhanta Darpana	European Values in 1899	Modern Values
Sun	365.25875	365.25843	365.25875	365.25637	365.25836
Moon	27.32167	27.32114	27.32167	27.32166	27.3216815
Mercury	87.9585	87.9699	87.9701	87.9692	87.969256
Venus	224.6985	224.9679	224.7023	224.7007	224.70080
Mars	686.9975	686.9979	686.9857	686.9794	686.97982
Jupiter	4332.3206	4332.2406	4332.6278	4332.5848	4332.589
Saturn	10765.7730	10765.8152	10759.7605	10759.2197	10759.23

Table 3: Inclination of the orbits of planets to the ecliptic (deg.-min.-sec.)

Planet	Surya Siddhanta	Siddhanta Shiromani	Siddhanta Darpana	European values in 1899	Modern values
Moon	4 30 0	4 30 0	5 09 0	5 08 48	5 08 33
Mars	1 30 0	1 50 0	1 51 0	1 51 2	1 50 59
Mercury	5 55 0	6 55 0	7 2 0	7 00 08	7 00 18
Jupiter	1 0 0	1 18 0	1 16 0	1 18 41	1 18 18
Venus	2 46 0	3 6 0	3 23 0	3 53 35	3 23 41
Saturn	2 0 0	2 40 0	2 29 0	2 29 40	2 29 10

doctrine and constructed a system of his own, combining the elements of the Ptolemaic and Copernican theories.

All our ancient astronomers subscribed to the geocentric hypothesis. Pathani Samanta, based on his own observations, proposed a different model in *Siddhanta Darpana*. The model is geocentric with Sun, Moon and stars revolving around the Earth. However, five planets Mercury, Venus, Mars, Jupiter and Saturn revolve round the Sun and the Sun with the planets around it revolve round the Earth (Fig.2). This model independently developed by Pathani Samanta is similar to the model developed by Tycho Brahe. To quote from the review of *Siddhanta-Darpana* in Nature:

"Prof. Ray compares the author very properly to Tycho. But we should imagine him to be greater than Tycho, for without the same assistance, without the encouragement of kings and the applause of his fellows, he has advanced his favourite science quite as effectually as did the Danish astronomer. It is specially curious to notice that the system at which Samanta Chandrasekhara ultimately arrived, and the explanation he offers to it, bears a very considerable resemblance to that which Tycho taught. The author has never been able to convince himself that the Earth turns on its axis or that it goes round the Sun; but to the planets he assigned heliocentric motion, much as Tycho did." Pathani Samanta died on June 11, 1904.

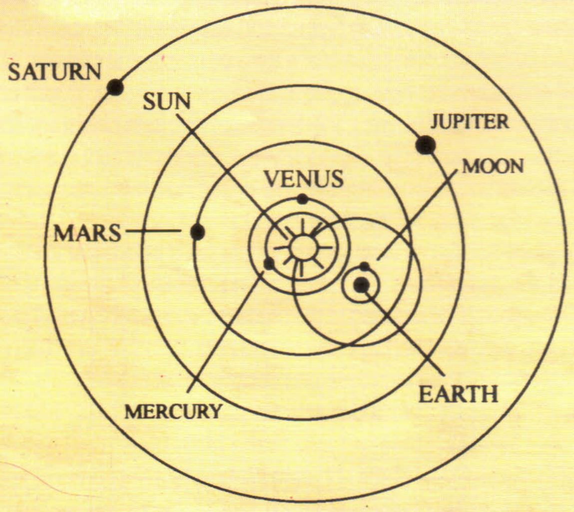


Fig. 2: Model proposed by Pathani Samanta.

The study of astronomy became a passion with him. Prof. J.C. Ray has informed us that Pathani Samanta could not be persuaded to stay in Cuttack even one day more after receiving the title of honour conferred on him by the British Government as eclipse of the Sun was to occur a few days later. He did not want such a momentous event to pass by unnoticed. He was honoured with the title of *Mahamahopadhyaya* on June 3, 1893 at a special conference for his significant contribution to the field of astronomy. He strived after knowledge for its own sake and that too, as Prof. J. C. Ray wrote, 'under difficulties whose magnitude is no less startling than the boldness of his attempt.' Finally we will end this article by quoting Prof. J. C. Ray:

"What has he (Pathani Samanta) done after all ?" – asks the impatient – critic. To him, I would say, is it not enough to find in this man a true lover of science who regardless of other people's unfavourable opinions of his work, their taunts and dissuasions, has devoted his whole life to the one pursuit of knowledge; who has shown the way to original research amidst difficulties serious enough to dishearten men in better circumstances: who has employed his time usefully, instead of frittering it away like the usual run of men of his rank, on a work which guides the daily routine of millions of his countrymen?"

Further Readings

1. *Mahamahopadhyaya Samanta Chandrasekhara Commemoration Volume*, Dukhisyama Pattanayaka (ed.), Directorate of Culture, Orissa, Bhubaneswara, 1990.
2. *Samanta Chandrasekhara: Life and Work*, P. C. Naik and L. Satpathy, **Current Science**, Vol. 69, No.8, pp.705-710, 1995.
3. *Jyotiska*, A Souvenir published on the occasion of All India Amateur Astronomers Meet (14-16 January 1995).
4. *Nature* 59, pp.436-437, 1899.
5. *Knowledge*, XXII, pp.257-258, 18899.

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Vigyan Prasar is shortly bringing out a monograph on the life & works of **Pathani Samanta**, *authored by Dr. P.C. Naik.*