

THE INDIAN TRADITION IN SCIENCE AND TECHNOLOGY: AN OVER VIEW

Any study of the Indian tradition of science has to start with linguistics. This is so not only because Linguistics is the earliest of Indian sciences to have been rigorously systematised, but also because this systematisation became the paradigm example for all other sciences of India.

Like all sciences and arts of the Indian tradition, Linguistics finds its first expression in the Vedas. For most of the Indian sciences, already by the Vedic period, the basic elements of study and the basic categories through which these are to be studied had been established, preliminary data for the operation of these sciences had been collected and rough systematisation had been achieved. Thus, for the science of Linguistics, in the *siksha* and *pratiakhya* texts associated with the various Vedas, we find a settled complete list of phonemes appropriately classified into vowels, semi-vowels, sibilants and the five groups of five consonants, all beautifully arranged according to the place of articulation which moves systematically from the throat to the lips. In fact phonetics and phonology are taken for granted by all authorities on etymology (*nirukta*) and grammar (*vyakarana*) including Yaska and Panini. In the *pratisakhya* literature one also find the morpho-phonemic (*sandhi*) rules and much of the methodology basic to the later grammatical literature.

The Indian science of Linguistics finds its rigorous systematisation in Panini's *Ashtadhyayi*. The date of this text, like that of much of the early Indian literature, is yet to be settled with any certainty. But surely the *Ashtadhyayi* is not of a date later than 500 BC*. In the *Ashtadhyayi*, Panini achieves a complete characterisation of the Sanskrit language as spoken at his time, and also manages to specify the way it deviated from the Sanskrit of the Vedas. Given a list of the root words of the Sanskrit language (*dhatupatha*) and using the sutras of Panini it is possible to generate all possible correct utterances in Sanskrit. This is of course the main thrust of the generative grammars of today that seek to achieve a purely grammatical description of language through a formalized set of derivational strings. It is understandable that till such attempts were made in the West in the recent past, the Paninian sutras to the Western scholars looked like nothing but some artificial and abstruse formulations with little content.

Patanjali (c 1st C BC) in his major commentary on the *Ashtadhyayi*, the *Mahabhashya* gives an elaborate rationale for the Paninian exercise. According to the *Mahabhashya* the purpose of grammar is to give an exposition of all correct utterances in the language. An obvious way to do this is to enumerate all correct utterances individually. This is how the celestial teacher Brihaspati would have taught the science of language to the celestial student, Indra. However for ordinary mortals, not having access to celestial time scales this method can apparently not be of much use. Therefore according to the *Mahabhashya* it is necessary to lay down general rules (*utsarga sutras*) with a wide application so that with a comparatively small effort men can learn larger and larger collections of valid utterances. What falls to fit in this set of general rules should than be encompassed in exceptional rules (*apavada sutras*), and so on.

In providing this characterisation of the science of grammar Patanjali laid his finger on perhaps the most essential feature of the Indian scientific effort. Science in India seems to start with the assumption that truth resides in the real world with all its

* The dates mentioned here are those based on Western scholarship. An indigenous Indian dating and chronology in this as in all other matters has yet to be established.

diversity and complexity. Thus for the Linguist what is ultimately true is the language as spoken by the people in all their diverse expressions. As Patanjali emphasises, valid utterances are not manufactured by the Linguist, but are already established by the practice in the world. Nobody goes to a linguist asking for valid utterances, the way one goes to a potter asking for pots. Linguist do make generalisations about the language as spoken in the world. But these generalisations are not the truth behind or above the reality. These are not the idealisation according to which reality is to be tailored. On the other hand what is ideal is the real, and some part of the real always escapes our idealisation of it. There are always exceptions. It is the business of the scientist to formulate these generalisations, but also at the same time to be always attuned to the reality, to always be conscious of the exceptional nature of each specific instance. This attitude, as we shall have occasion to see, seems to permeate all Indian science and makes it an exercise quite different from the scientific enterprise of the West.

In the tradition of Linguistics after the period of *Mahabhashya* the major attempt of the grammarians seems to be to provide refinements and simplifications of Panini. In this period a number of Sanskrit grammars are written. One of them, *Siddhanta Kaumudi* (c.1600) became eminently successful, perhaps because of its simplicity. These attempts continue till the 19th century. Another form of study that became popular amongst the grammarians is what may be called the philosophical semantics, wherein one starts with an utterance and by analysing it into its basic grammatical components tries to fix and characterise its meaning. This of course, is the major application for which grammar is intended in the first place.

Other Indian language grammars were written using Paninian framework as the basis. In fact these grammars are not fully formalised grammars in the sense of Panini. Instead what is attempted is to start with the Paninian apparatus and specify the transfer rules from Sanskrit as also the specific morpho-phonemic rules (*sandhi*), for the language under consideration. Such grammars for various Prakrit languages of the North and also the South Indian languages continued to be written till the 18th century, so much so that in the 16th century Krishnadas wrote a grammar for the Persian language. *Parasi Prakash* styled on the grammars of the Prakrit languages.

II

Among the sciences of the Indian tradition Astronomy and Mathematics also occupy an important place. Indian mathematics finds its early beginnings in the famous *Shulva* Sutras of the Vedic times. Purportedly written to facilitate the accurate construction of various types of sacrificial altars of the Vedic ritual, these sutras lay down the basic geometrical properties of plane figures like the triangle, the rectangle, the rhombus, and the circle. Basic categories of the Indian astronomical tradition were also already established in the various *Vedanga Jyotisha* texts.

Rigorous systematisation of Indian astronomy however begins with Aryabhata (b.470 AD). His *Aryabhatiya* is a concise text of 121 aphoristic verses containing separate sections on the basic astronomical definitions and parameters, basic mathematical procedures in arithmetic, geometry, algebra and trigonometry, methods of determining mean and true positions of the planets at any given time, and description of the motions of sun, moon and the planets along with computation of the solar and lunar eclipses. After Aryabhata, one comes across a long series of illustrious astronomers with their equally illustrious texts, many of which gave rise to a host of commentaries and refinements by later astronomers and became the corner stones of flourishing schools of astronomy and of Varahamihira (d.578 AD). Brahmagupta (b.598 AD),

Bhaskara 1 (b.629 AD). Lalla (C.8th C AD), Munjala (932 AD, Sripati (1039 AD), Bhaskara II (b.1114 AD), Madhava (c.14th C AD), Parameshwara (c.16th C AD), Nilakantha (c.16th C AD), Jyeshthadeva (c.16th C AD), Ganesha Dalvajna (c.16th C.AD) and a host of others. The tradition continued and thrived right upto the late eighteenth century, and in regions like Kerala, original work in the Indian tradition continued to appear till much later.

The most striking feature of this long tradition of Indian mathematics and astronomy is the efficacy with which the Indians seem to be handling and solving rather complicated problems. Thus in Mathematics the Indians already in *Shulva sutras* know all the basic theorems of plane geometry. Around this time they also develop a sophisticated theory of numbers including the concepts of zero, and negative numbers. They also seem to have arrived at simple algorithms for all basic arithmetical operations by using the place value notation.

Thus by the time of Aryabhatiya the Indians have all basic mathematical concepts and procedures that are today taught at the high school level. By the 10th or 11th century they are able to solve sophisticated problems in algebra such as second order Diophantine equations. By the 14th century infinite series for sine and cosine functions are written down in trigonometry. High levels of approximations of π and recognition of its irrational character are also achieved by the same time.

The reason for this success of the Indian mathematicians lies perhaps in the explicitly algorithmic and computational nature of Indian mathematics. The objective of the Indian mathematician was not to find ultimate axiomatic truths in mathematics but to find methods of solving specific problems that may arise in the astronomical or other contexts. For the purpose the Indian mathematicians were prepared to set up simple algorithms that may give only approximate solutions to the problem at hand, and to evolve theories of error and recursive procedures so that the approximations may be kept in check. This algorithmic methodology persisted in the Indian mathematical consciousness till recently so that Ramanujan in the twentieth century seems to be chalking up his impressive mathematical discoveries perhaps through the use of this traditional Indian methodology.

The same pragmatic concern to be able to calculate the positions of the various planets and eclipses of the sun and the moon reasonably accurately, informs the efforts of the Indian astronomers. And in this they turned out to be eminently successful. In their calculations Indians often take the beginning of the *Kaliyuga* in the year 3102 before Christ as their starting point, and the so-called *Siddhanta* texts deal with a much larger period consisting of 43,20,000 years called a *Mahayuga* or sometimes even a period 1000 times the above, which is called a *Kalpa*. In spite of dealing with such long time periods the Indian astronomers were able to keep their techniques fairly simple and their parameters fairly well refined so that even towards the end of the eighteenth century and early parts of nineteenth, when the active astronomical tradition had become dormant in large parts of India, European astronomers are able to locate Brahmins in South India, who could calculate for them the details of the current eclipses to an accuracy comparable to, and often better than the best calculations of Europe of the time.

The reasons for the simplicity and accuracy of the Indian astronomical techniques are again to be found in the pragmatic attitude of the Indians towards the sciences. The Indian astronomers were in the business to calculate and to compute; but not to form pictures of the heavens, as they ought to be in reality. Indian astronomers do use some geometrical models but these are supposed to be nothing more than artefacts necessary to perform their calculations (see Appendix). It is obvious that the

astronomical parameters obtained using such artefacts will get out of tune with reality sooner or later and the calculations made with such parameters will start deviating from actual positions of the planets. Indian astronomers are aware of this and were quite willing to take up the onerous task of continuously observing the skies, continuously checking their computations against observations and repeatedly re-adjusting their parameters so as to make their calculations accord with reality. Thus the sixteenth century astronomer Nilakantha Somasutvan, finding a contemporary commentator lamenting about the different times given in different *Siddhantas* and the computed times differing from the actual ones, exhorts.

O faint hearted, there is nothing to be despaired of one has to realise that five *Siddhantas* had been correct at a particular time. Therefore one has to search for a *Siddhanta* that does not show discord with the actual observation at the present time. Such accordance has to be ascertained by observations during time of eclipses, etc. When *Siddhantas* show discord observations should be made with the use of Instruments and correct number of revolutions etc, found, and a new *Siddhanta* enunciated.

A little later Jyesthadeva in the *Drikarana* tells how from aryabhata to the present day the astronomers have adjusted the parameters to accord with observations and how he too is doing the same job for his times and he ends with the statement that henceforth too the deviations that occur should be carefully observed and revisions effected.

III

The third major science of the classical tradition is *Ayurveda*, the science of Life. Like Linguistics and Astronomy this too finds its early expression in the Vedas, especially the Atharvaveda in which a large amount of early; medicinal lore is collected. Systematisation of *Ayurveda* takes place during the period 5th century BC and 5th century AD in the *Charaka Samhita Sushruta Samhit* and the *Ashtanga Sangraha*, the so called Brihat trayee texts, which are still popular today. This is followed by a long period of intense activity during which attempts are made to refine the theory and practice of medicine, and to bring more and more information into the stream of systematic medicine. This process of accretion of information and refinement of practice continued right upto the beginning of the nineteenth century.

Like in Linguistics and Astronomy, the remarkable feature of Indian tradition of medicine is its pragmatic attitude towards scientific theorization. The Ayurvedic texts while providing a theoretical framework through which the problem of finding an appropriate cure for a particular patient must be approached, never tire of reminding the practitioner that he must be constantly observant of all the specific features that a particular case presents in fact for Charaka Samhita the most desirable intellectual accomplishment of a doctor is that of possessing Yukti, the Yukti is the capacity of the trained intellect that manages to see the course of action through the complexity of phenomena with their multiple causes.

The attitude of Ayurveda towards theoretical generalisations is very clearly brought out in a revealing verse of Sushruta Samhita. While describing the theoretical qualities of a substance through which its medicinal properties are to be determined, the text comes

up with the warning that the wise physician should never raise theoretical arguments about the properties of a drug when they are already known and established in tradition based on actual practice, because after all a thousand reasons will not make the drugs of the *ambastha* group perform laxative functions. Therefore the physician must rely on what is established in tradition based on actual practice, rather than acting exclusively on his theoretical reasoning. This attitude towards theory gives the *Ayurvedic* texts, a refreshing openness and a surprising keenness of observation. Nothing that may have any effect on the problem of health seems to escape the observation of the physicians. One finds the physicians worrying about the differing aspects of the seasons, the soils, the waters and so on. And in the therapeutic sections they bring into use all their theoretical understanding and all the folk practices that have been proved to be efficacious in tradition.

This pragmatic attitude towards scientific theoretization made the doing of science in India a rather painstaking business. The Indian scientists not having the luxury of reducing the reality of the world to that encompassed by their theories of the time, had to be continuously aware of the world in its complete complexity, and had to continuously refine and simplify their procedures in order to operate successfully in this complex world. That they were able to do this systematically in a number of fields over a long period of over 2000 years is measure of their ingenuity and industry. Thus one can only marvel of the stupendousness of the task of encapsulating the whole of Sanskrit language as it was spoken in 4000 aphoristic rules. Equally remarkable is the effort of the astronomer- mathematicians to repeatedly refine their parameters to fit the observations so that ever since Aryabhata the Indians always had access to reasonably accurate information about the motions of the heavens. But the astronomer mathematicians also simplified their computations to an extent that learned Brahmins in their innumerable locales could also compute all the astronomical information that mattered to the residents. The effort of Indian physicians also falls in the same class. They were not only able to painstakingly acquire and systematize within their theoretical framework all the information about drugs and diseases that was current amongst the people in diverse areas, but were also able to simplify their theories sufficiently so that much of the *Ayurvedic* science became the folders of health known in all families. The fact that the Indian scientists given their theoretical attitude had to be necessarily open to the world around them perhaps ensured that the folk and the science had to remain in a symbiotic relation with each other.

Besides Linguistic, Astronomy and Mathematics, and Medicine, Indians also developed the sciences of matter (*Padartha Sastra*), metallurgy (*Rasa Sastra*), architecture (*Vastu Sastra*), music (*Sangitha Sastra*) etc. To all of these sciences they brought their peculiarly Indian mode of careful but tentative generalisations and continuous keen observation.

IV

The pragmatic attitude of conceptual sophistication and operational simplicity that we have noticed amongst the sciences of India seems also to have informed the Indian technologies. A systematic history of the traditional Indian technologies is yet to be written. Therefore one has to rely largely on the accounts of European travellers and administrators who observed and wrote about the Indian practices during the early phase of European conquest of India.

The major technological endeavour of India was of course in the field of agriculture. Col. Alexander Walker writing in the early nineteenth century seems to have been amazed at the keen interest that ordinary Indians showed in everything connected with agriculture. He is also greatly impressed by the care with which the Indian cultivators tended their fields, so that to him the fields of Malabar and Gujarat seem more like carefully laid out gardens. This care is coupled with an intimate knowledge of the soils, the seasons and seeds. The Indians seemed to have mastered techniques of rotation of crops, irrigation, manuring, and selection of seeds etc. from very early times. These techniques had been so well studied and so optimised to the peculiar conditions of each area that John Voeicker, the Consulting Chemist to the Royal Agricultural Society, sent to India towards the end of the nineteenth century to suggest ways of improving Indian agriculture through the use of chemistry, could recommend little by way of technological changes. He was of the opinion if only the traditional facilities of water and manure could be ensured the farmers of India could obtain the best possible yields. As for suggesting improvements he seemed to have felt that it was much easier to propose improvements in English agriculture, than to make really valuable suggestions for that of India. Another expert of early twentieth century John Kenny, remarks in the same vein that he did not consider it wise to suggest seed selection in a land where 4000 different sorts of paddy are grown in one province alone and carefully differentiated according to their qualities and land suitable for them.

The implements of the Indian cultivator often seemed rough and primitive to the occasional observer. However it was soon realised that these implements were fully adapted to the particular conditions in which they operated and even in the late nineteenth century nothing could be suggested by way of their improvement. In fact an early experiment during the later half of the eighteenth century to introduce the heavy English plough near Salsette on the west coast had proved a total disaster. In 1795 Capt. Thos Holcott reported on the sophistication of the Indian drill plough widely used in the Andhra region. The drill plough till then was considered a modern European invention.

With their simple but sophisticated implements and their meticulous techniques of agriculture, the Indian farmers were able to obtain impressive yields. It was reported that in early nineteenth century in the Allahabad region the produce of an acre of land amounted to over 55 Bushels per harvest while that in England around the same time was only about 20 Bushels. Since the Indian farmer in this region usually produced two crops a year, the annual yield of each acre may be taken as over 110 Bushels at his time. The productivity of Indian agriculture, however, declined very rapidly during the nineteenth century. But even in the 1890s lands which had access to irrigation and manure yielded harvests comparable to those in England, and larger than the harvests obtained those days in Europe, USA and Australia.

V

The Indian technical ingenuity in evolving simple techniques that are sophisticated enough to take advantage of the full complexity of the local situation, and then meshing these local techniques into a large impressive system can be best seen in the tank irrigation system of South India. It seems that the whole of South India was dotted with these tanks. A British expert writing in the 1850s estimated the total number of such tanks in the Madras Presidency to be over 50,000. Another estimate indicates that in the eighteenth century there were more than 38,000 tanks in the region, which later constituted the Mysore state. The state had an area of around 29,500 square miles. It is, therefore, fair estimate that there were over a lakh tanks in whole of South India. From what is known of the political circumstances of the time it

is clear that these tanks were constructed and maintained by local effort. However, together they formed a closely knit whole so that the outflow from the one at a higher level supplied the one at a lower level, and so on. This chain of tanks was so complete and inter related within itself that the British engineers of the nineteenth century felt that it would have been impossible to add another tank to the chain.

The Indian genius for performing vast tasks through simple, small and dispersed techniques is seen even better in the case of metallurgy. Early European observers noticed the Indians using small furnaces for something and refining iron and making steel. Scores of seventeenth, eighteenth and early nineteenth century accounts of Indian manufacture of iron and steel are available, and these pertain to perhaps a hundred districts spread all over India. The smelting furnaces described in these accounts seem to be of quite rough construction from the outside. However, the observers noticed that the internal proportions and various angles needed to be rather exact, and there were cases where the furnace had to be demolished and reconstructed to correct some minor error in the angle of blast, or in some internal proportion. Yet these sophisticated furnaces were routinely constructed by the Indian iron-smiths in a matter of hours without the help of any very complicated instruments.

These furnaces worked quite efficiently by the standard of those times. Thus, according to one detailed account, two units of charcoal were sufficient to produce one unit of crude iron in these furnaces. Processes of refining iron and steel making were also equally efficient. Steel was prepared by direct carbonisation of Iron in closed crucibles in which green leaves, wood and charcoal were all put together. This process seemed mysterious to the British observers, since a process of direct conversion was discovered in Europe only in the 1920 s. Even then, observers were often surprised at the quickness with which steel was made in the Indian furnaces, the process taking a few hours compared to many days taken in the corresponding European processes.

The simplicity of these Indian techniques should be seen in the context of the fact that Indian iron and steel had been renowned for their qualities for centuries past. All over India one can find scattered Iron pillars and girders of very high quality, especially as regards corrosion resistance. Indian steel has an equally distinguished record of maintaining excellent quality, and even in the late eighteenth century an expert in Britain when presented with a sample of Indian steel noted that it was excellently adapted for the purpose of fine cutlery, and particularly for all edged instruments used for surgical purposes .

It is worth remarking that with their small and dispersed furnaces, which produced perhaps half a ton of iron during a week s operation, Indians were capable of producing a rather large amount of iron and steel. According to some nineteenth century enumerations there were hundreds of such furnaces operating in certain districts and taluks. On the basis of this information it has been estimated that the total number of furnaces throughout India in the later part of the eighteenth century could have been over 10,000 and these furnaces together had the potential to produce some 2 lakh tonnes of iron annually.

A survey of Indian technologies cannot be complete without some discussion of textiles, the great industrial enterprise of pre-British India. Upto 1800 India was the world's leading producer and exporter of textiles. Yet this production was almost entirely based on techniques that could be operated at the level of the individual or the family. Spinning of yarn was an activity in which perhaps whole of India participated. According to an observer from Manchester, Amo Pearse, who in 1930 visited India to study its cotton industry, there were probably 5 crores spinning wheels (Charkhas) intermittently at work even then. And this simple small wheel was so efficient that till the early decades of the nineteenth century a widowed mother could still maintain a whole family in reasonable manner by spinning on the charkha for a few hours a day. Weaving was a relatively more specialised activity. However, the number to those belonging to the weaver castes was smaller in comparison only to those from the cultivating castes. Early nineteenth century data for certain districts of South India indicate that each district had around 20,000 looms. Amo Pearse in 1930 estimated the number of handlooms operating in India to be in the vicinity of 20 lakhs.

There were vast regions of India, which specialised in specific types of fabrics. Each of these areas developed techniques of weaving, bleaching, dyeing and painting etc., that were indigenous to the region, and also had its own characteristic designs, motifs and symbols. For example, in Western India alone, Sironj in Rajasthan and Burhanpur in Khandesh were major centres of cotton painting cheap printed cottons came from Ahmedabad; woollens including the extra-ordinary Cashmere Shawls were produced in Kashmir, true silks were worked as Patolas at Patan in Gujarat and so on.

These dispersed and diverse techniques were so optimised that textile produced in Britain through the post industrial revolution British technology could hardly match the Indian textiles in quality or price. Till the early nineteenth century, mill produced fabric had to be protected from Indian competition by the imposition of duties of 70 to 80 percent on the cottons and silks imported from India or, by positive prohibition. As the historian H.W.Wilson notes, without such prohibitory duties and decrees, the mills of Paisley and Manchester would have been stopped in their outset and could scarcely, have been again set in motion even by the power of steam.

The Indians had developed their locality specific techniques not only in agriculture, irrigation, metallurgy and textiles, but also in diverse other areas like building and construction, sculpture, pottery, making of glass, and even luxuries like making of Ice etc. That is perhaps why most historians of pre-British India are agreed that India of that time was not only an agricultural, but also an industrial society.

Appendix: Computations in Indian Astronomy By M.D.Srinivas

To get a flavour of the Indian way of doing Astronomy and Mathematics, it may be instructive to look at the way they make particular Astronomical calculations like for example the calculation of the longitudes of the *grahas* (the sun, the moon and the various planets) at any given time. The following are the essential steps.

1. The Indian Astronomers first compute the *shargana* or the total number of mean solar days elapsed from the chosen epoch till the given date, specified as such and such *Sakabda* (Saka year) *masa* (lunar month) and *tithi* (lunar day). For this, they first compute the number of *adhikamasas* (intercalary

lunar months) elapsed since the epoch till the beginning of the current Saka year. From this the number of *tithis* elapsed since the epoch till the given date is calculated. Then the number of *kshyahas* (omitted lunar days) from the epoch are computed and this when subtracted from the number of *tithis*, gives the *shargana* for the given data. The computation of the number of *ashikamasas* and *kshyahas* is based on specified basic astronomical parameters, such as the mean motions of the sun and the moon.

2. From the computed *shargana*, the mean longitudes (*madhyama graha*) of the sun, the moon and planets are calculated using the specified values of mean (daily) motions of these *grahas*.
3. To take care of the irregular motion of the *grahas* a series of corrections are applied to the *madhyama graha* mean longitude to get *sphuta graha* the true longitude. For the case of planets the basic corrections are the *manda karma* and the *sighra karma*. For the (outer) planets-Mars, Jupiter and Saturn the *manda karma* is roughly the equation of centre which takes care of the non-circular orbit, and the *sighra karma* converts the corrected heliocentric longitudes into the corrected geocentric longitudes. The basic form of the *manda* and *sighra* corrections are obtained from a geometric epicyclic (or eccentric) model and involves the mean motions of the apsides (*mandocche* and *sighroccha*) and the circumferences (*manda paridhi* and *sighra paridhi*) of the epicycles, as the basic parameters. However, what every text of Indian astronomy prescribes is a series of *manda* and *sighra* type of corrections performed iteratively till the results show a convergence to desired accuracy. The actual steps involved in this sequence of corrections depend on the particular planet and also varies from one school of astronomy to another. This procedure seems to enable the Indian astronomers achieve much better fit with observations than those achieved in other ancient traditions of astronomy which operative with ideal geometrical models of planetary motion involving epicycles, equants, etc. This sequence of operations is what enables the Indian astronomers to incorporate for instance some of the higher order corrections to the equation of centre which in modern astronomy are calculated using the Kepierian orbits, etc.
4. The above planetary position is as observed at the time of sunrise (or midnight in some schools of Indian astronomy) at the Indian zero meridians passing through Ujjain. The *desantara* correction is applied to calculate the planetary position at sunrise of places on a different meridian.
5. Finally, the planetary position at any given time of the day or night is calculated from that at sunrise (or midnight) by using the so called *sphutagati* or the true daily motion of the planet. This calculation also involves the knowledge of the latitude of the place. Further it is necessary to know whether the planet is in retrograde motion by computing the so called *sighragati phala* in computing these *gatis* or velocities, various formulae which are obtained by procedures which tantamount to differentiation of the expressions for the *sighra* and *manda* corrections, are used.

The basic astronomical parameters involved in the above calculation are the mean motions of the sun, the moon and the various planets, their apsides, and the circumferences of the *manda* and *sighra* epicycles, etc. These have to be determined on the basis of careful observations made over long periods. Each text of Indian astronomy gives the values for these parameters current at its time.

Further Reading Material:

1. Sirisa Chandra Vasu : The Ashtadhyayi of Panini, Edited and Translated into English, 2 vols. Allahabad 1891(Reprint Delhi 1962).
2. Kashinath Vasudev Abhayankar : Patanjali s Vyakarana Mahabhashya: Ahnikas 1,2 Edited and Translated into English, Poona 1967.
3. T.A.Saraswati Amma,Geometry in Ancient and Medieval India, Delhi. 1979.
4. B.Datta and A.N.Singh: A History of Hindu Mathematics, Parts 1 and 2 Bombay 1962, Part 3 reavised by K.S.Shukla, Ind.Jour. History of Science 18 (1983).
5. K.V.Sharma and B.V.Subharayyappa: A Source Book of Indian Astronomy,Bombay 1985.
6. D.Arka Somayaji: Indian Astronomy, Dharwar 1971.
7. Charka Samhita : Edited with English ,Gujarati and Hindi Translations, 6 vols. Jamnagar 1949.
8. Kunjalal Bhisagratna : Susruta Samhita, Edited and Translated into English, Varanasi 1963.
9. Dharampal : Indian Science and Technology in the Eighteenth Century, New Delhi 1971.
10. Claude Alvares : Homo Faber, Delhi 1979.
11. Madras Group : Indian Agriculture at the Tum of the Century, PPST Bulletin No.4, Nov.1982.

Dr.J.J.Bajaj