# The Astronomical Code of the Ṛgveda

(Third Edition)

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To Ram Nath Kak
*father, guru and friend*

The first edition of this book was published by Aditya Prakashan, Delhi in 1994 and the second edition was published by Munshiram Manoharlal, New Delhi in 2000. This Third Edition may be copied or archived for individual use freely.

# The Astronomical Code of the Ṛgveda

This is the third revised edition of the classic book that presented the author's discovery of the astronomical code in the organization of the Ṛgveda. This code has changed our understanding of the Vedic system of knowledge, rise of early astronomy, history of science, and the chronology of ancient India. This edition has a new chapter on the connections between Vedic and Babylonian astronomy.

Some comments on the discovery of the code:

- I had suspected for a long time that there was something to the Ṛgveda which went for a beyond what our philology and history could read out. *Here it is!* [This is an] epoch-making discovery.
  -- Professor Klaus K. Klostermaier, University of Manitoba

- Truly singular achievement.
  -- Professor Miguel de Mora, National Autonomous University of Mexico

- It has been shown that the numbering of the hymns in the books of the Ṛgveda reflects the number of bricks used for building the fire altar as indicated in the Śatapatha Brāhmaṇa A monumental accomplishment.
  -- David Frawley, Director, American Institute of Vedic Studies, Santa Fe, New Mexico

- This code elegantly and effortlessly makes sense of [many] peculiarities of the Vedic tradition.
  -- Björn Merker, Vedic scholar, Helsingborg, Sweden

**Subhash Kak** is a widely known scientist and Indologist. Currently Regents Professor and Head of Computer Science Department at Oklahoma State University, he has authored 20 books and more than 300 papers in various fields. Apart from his work on Vedic astronomy, he has researched linguistics, quantum theory, and history of science. He was editor for India for UNESCO's ICOMOS project on archaeoastronomy during the International Year of Astronomy 2009.

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# *Preface*

The Ṛgveda has been studied in India for more than four millennia and in the West for a couple of centuries, but until recently no one suspected that the organization of the book held any secrets. It was recognized that many passages in the hymns were enigmatic, but these and the book's many riddles were believed to be part of a deliberate style to communicate the paradoxical nature of consciousness and reality. It was generally accepted that the Ṛgveda spoke of the deepest mystery in poetic form. No one saw any evidence of hard science.

How then did I stumble on the astronomical code of the Ṛgveda? The answer to this isin that my starting point was different. It was taken as axiomatic that Vedic thought was *pre-scientific* which was defined by the well-known Vedic scholar Jan Gonda as[1]

> speculations of archaic times (in) the tendency to draw inferences, deduce rules, identify or recognize connections on the strength of inherence, participation, partial resemblance, similarity of function and so on.

The question arises: In what sense is pre-scientific different from scientific? Philosophers of science such as Thomas Kuhn have shown that scientific structures are characterized by systems of analysis within the framework. Science deals with metaphors. Although quantification and measurement are helpful in the development of a scientific discipline, they do not characterize all scientific enterprise. Science is the use of logic in studying categories in terms of others, and some of these might be related to physical observables. The term pre-scientific has no meaning: a study is either scientific or not.

The notion that there is no science in the Ṛgveda is an article of faith, which is subject to refutation. Theories about the rise of Vedic society, in which the Vedic Indians were taken to be invading barbarians, lulled scholars into a false view. It led to the rejection of evidence that went counter to this model, as being allegedly muddled or simply unreliable.

My inquiry began in seeking answer to the puzzle: How can the Vedic texts suggest a subtle understanding of the nature of consciousness and yet have no quantitative science? During the sixties and seventies, A. Seidenberg did pioneering work investigating the nature of geometrical knowledge in the Śatapatha Brāhmaṇa. I discovered that this geometrical knowledge was expressed in relation to astronomical questions, and I soon discovered the astronomical basis of Vedic altars. But from the scientific underpinnings of ritual to the organization of the Ṛgveda was still a giant leap.

Scientists like Jacques Hadamard, Henri Poincaré and Roger Penrose have described how their discoveries were made suddenly, in an intuitive flash.[2] My own discovery was triggered by an essay in a popular magazine in November 1992 pointing out the marvelous coincidence that the moon and the sun are nearly of identical size when viewed from the earth. I had an overpowering feeling that the matter of size had something to do with the structure of the Ṛgveda. Checking the text in my library, I quickly discovered that the number of hymns encoded facts about the passage of the sun and the moon. The next task was to make sure that the correspondence was not just a coincidence, which required a careful sifting of numerical and textual data. I later found a confirmation of these numbers in the structure of the Atharvaveda and the Bhagavadgītā.

There are those who argue that human progress can be measured only in terms of scientific progress. To such people the question of the science of the Ṛgveda is of much importance, for it is the oldest complete book that has come down to mankind.

Scholarly opinion has often swung between two extreme views on the past: one barbaric, the other idyllic. In truth, the past was much more of a complex affair than suggested by either of these labels. The discovery of the astronomical code not only allows us a new look at the rise of early science, it also focuses on the need to find the developmental process at the basis of the hymns.

Since the first edition of the book came out 6 years ago (in 1994, published by Aditya Prakashan, Delhi), new discoveries have validated its basic conclusions. We have found evidence of the knowledge of the asymmetric circuit of the sun in the Śatapatha Brāhmaṇa. Our understanding of the Purāṇic cosmology has become clearer. It is possible now to see the rise of Indian astronomy in several stages culminating in the early Siddhāntas of 2,000 years ago. Since we have an existing tradition on the authorship of the hymns, this can help with the question of the chronology of the hymns.

The past few years have also seen dramatic new findings in art and archaeology. The earliest Indic art, preserved on rocks in the palaeolithic, mesolithic and neolithic stages has been traced to 40,000 years before our time. New evidence has emerged on the influence of Indic ideas on Greek art of the second millennium BCE. More evidence of the continuity of the Harappan civilization, traced back to about 8,000 BCE, with the classical Indian culture has emerged.

The first seven chapters of the revised edition are a lightly updated version of the previous material. New material, that recently appeared in various journals, goes to form the new chapters 8-12.

It was my father's great wish to see me write on ancient history, and he was very pleased with my research on history of science. He followed my work on the astronomical code with the greatest interest, and he was always there with advice, encouragement and inspiration as the work unfolded. Six years ago, we were both busy writing: he his autobiography, and I this book. To my greatest regret, he did not live to see my book in print. I dedicate this book to him.

Baton Rouge, May 20, 1999 Subhash Kak

## Third Edition

I am delighted that the 3rd edition of the book is being published. This edition has an extra chapter on the connections between Vedic and Babylonian astronomy.

Stillwater, January 26, 2011 Subhash Kak

# 1. Introduction

The Ṛgveda speaks of fire altars symbolizing the Vedic system of knowledge. The fire altars, built of bricks in elaborate designs, are described in great detail in the Taittirīya Saṃhitā, the Śatapatha Brāhmaṇa and other texts. These altars were built to different designs and in specific relationship with each other and with the dimensions of the larger ground.

It is generally accepted that the geometric constructions of the fire altars represent the earliest Indian mathematics and geometry. We show that these constructions merely formalize what must have been the mathematical knowledge of the Ṛgvedic times. It was assumed that the altars were an end in themselves, which is why no attempt was made to examine the logic behind their designs.

This book shows that there is an astronomical basis to the design of Vedic altars and we furnish proof of this from the Vedic texts. Given that the Saṃhitās and the Śulbasūtras proclaim that the Vedic hymns are an altar of mantras, we find an astronomical basis of the organization of the Ṛgveda itself.

There are a large number of astronomical references in the Vedic texts. The Śatapatha Brāhmaṇa gives the names of twenty seven nakṣatras and an equal number of upa-nakṣatras. On the other hand, the Taittirīya, the Atharva, the Kāṭhaka and the Maitrāyaṇī Saṃhitās give the names of twenty eight nakṣatras. The difference of one nakṣatra appears to represent two traditions trying to reconcile observation to theory in different ways. Many other constellations are also mentioned which makes clear that the Vedic people were much concerned with astronomical phenomena.

There is early reference to a six-day week that is called the ṣaḍaha[1] and to a seven-day week. The Taittirīya Saṃhitā speaks of six seasons related to the months as follows:

Vasanta (Spring) : Madhu (Caitra), Mādhava (Vaiśākha)
Grīṣma (Summer) : Śukra (Jyaiṣṭha), Śuci (Āṣāḍha)

Varṣā (Rains) : Nabha (Śrāvaṇa), Nabhasya (Bhādrapada)
Śarada (Fall) : Iṣa (Āśvina), Ūrja (Kārttika)
Hemanta (Winter) : Saha (Mārgaśira), Sahasya (Pauṣya)
Śiśira (Cold) : Tapa (Māgha), Tapasya (Phālguna)

Sometimes hemanta and śiśira were taken together and there is mention of five seasons. The division into five seasons appears to have been prompted by the symmetry with the five-year yuga.

Hitherto historians of science have seen the Vedāṅga Jyotiṣa of Lagadha as summarising Vedic astronomical knowledge. This is a very late book which is not a treatise on astronomy but rather served as a manual for the determination of the times for rituals. Based on this text it is not possible to say what else the Vedic Indian might have known of astronomy. The dating of the Vedāṅga Jyotiṣa has been assumed based on the statement[2] that in Lagadha's time the winter solstice was at the beginning of the nakṣatra Śraviṣṭhā (Delphini) and that the summer solstice was at the mid-point of the Āśleṣā nakṣatra. This implies c. 1300 BCE.

## Siddhāntas

Apart from the Vedāṅga Jyotiṣa are the more complete manuals of astronomy called the Siddhāntas. Some of the early Siddhāntas are summarized in Varāhamihira's Pañcasiddhāntikā. How far back the Siddhāntas go in time is unknown. But if the Paitāmaha Siddhānta is named after Bhīṣma Pitāmaha of the Bhārata War, as has sometimes been suggested, then the Siddhāntas represent a tradition of astronomy, broader than the Vedāṅga Jyotiṣa, that goes back to the close of the Ṛgvedic age.

Support for this view comes from Varāhamihira's own ranking of the five Siddhāntas. Of Paitāmaha, Vāsiṣṭha, Romaka, Pauliśa and Saura he considers the Sūrya Siddhānta to be the best, followed next by the Pauliśa and the Romaka as being almost equally correct, and declaring the remaining two to be much inferior. It stands to reason that accuracy of these works is related to the recency of the observations and Paitāmaha and Vāsiṣṭha must have been old Siddhāntas. It is also likely that the old Siddhāntas were, like the Purāṇas, revised during the course of centuries. Nevertheless, it is significant that there is a lot of correspondence in the methods of the Paitāmaha Siddhānta and the Vedāṅga Jyotiṣa.

Once we recognize the beginnings of astronomy in the Ṛgveda itself, it becomes possible to understand the evolution of this science to the later Siddhāntic astronomy. It also becomes possible to understand the reasons for the parallels between ancient Indian and other astronomical systems. These parallels are:

- The division of the zodiac into twenty seven or twenty eight asterisms. This is common to the Indian, Arabian and the Chinese systems.
- The solar division of the zodiac into twelve parts. This division as well as the names are common to the Indian and the Greeks.
- The theory of epicycles has many points of commonality in the Indian and the Greek systems.
- There are parallels in the system of astrology amongst the Indians, the Greeks and the Arabs.
- The names of the five planets and the names of the days of the week have commonality amongst the Indians and the Greeks.

The Vedic textual evidence takes us to at least the third millennium BCE from their specific ordering into twenty seven or twenty eight since we know that the order of their listing in chronologically attested later texts was different. The Vedic system of knowledge, with an assumed linkage between astronomical and terrestrial events, implies a system of astrology as well. The planetary periods evidence from the Ṛgvedic code is at least a thousand years before such knowledge outside India. With these dates and the attested presence of the Vedic Indians in West Asia in early second millennium BCE, it becomes easy to see how the astronomical ideas of the fire altars and the Ṛgveda could have been transmitted to Babylonia and Greece.

One finds that the remarks of Ebenezer Burgess, the translator of the Sūrya Siddhānta, on the relationship between Indian and Greek astronomy to have been very prescient:[3]

> In reference to most [of the above points], the evidence of originality I regard as clearly in favor of the Hindus; and in regard to some, and those the more important, this evidence appears to me nearly or quite conclusive... As to the lunar division of the zodiac... the undoubted antiquity of this division among the Hindus,

> in connection with the absence or paucity of such evidence among any other people, incline me decidedly to the opinion that the division is of a purely Hindu origin.
>
> As to the solar division ... this was known to the Hindus centuries before any traces can be found in existence among any other people.
>
> The theory of epicycles. The difference in the development of this theory in the Greek and Hindu systems of astronomy precludes the idea that one of these people derived more than a hint respecting it from the other. And so far as this point alone is concerned, we have as much reasons to suppose the Greeks to have been the borrowers as the contrary; but other considerations seem to favor the supposition that the Hindus were the original inventors of this theory...
>
> As to the names of the planets, I remark that the identity of all of them in the Hindu and the Greek systems is not to my mind clearly made out.
>
> And in regard to ... data and results—as for instance, the amount of the annual precession of the equinoxes, the relative size of the sun and the moon as compared with the earth, the greatest equation of the centre for the sun—the Hindus are more nearly correct than the Greeks, and in regard to the times of the revolutions of the planets they are very nearly as correct: it appearing from a comparative view of the sidereal revolutions of the planets, that the Hindus are most nearly correct in four items, and Ptolemy in six. There has evidently been very little astronomical borrowing between the Hindus and the Greeks. And in relation to points that prove a communication from one people to the other... I am inclined to think that the course of derivation was from east to west rather than from west to east.

Burgess was right so early in his review as he was not burdened by the baggage of the theory of Aryan invasions. Since his time, it took us more than a hundred years before archaeological findings helped to rid us of our misconceptions regarding ancient India.

## System of Knowledge

It is generally agreed that the hymns of the Ṛgveda represent poetry from a period of several centuries. Nevertheless, it is typical that reviews of Ṛgveda[4]make no attempt to give a developmental analysis of the hymns. The reason behind this is that the Ṛgveda is considered no more than inspired poetry and mythology, in which there is no reason to look for any distinct, evolutionary stages.

But the view of Ṛgveda being one undifferentiated mass goes against the textual evidence. The Veda means knowledge. When the Vedic Saṃhitās are taken together with the Brāhmaṇas, Āraṇyakas, Upaniṣads, Sūtras, Vedāṅgas and the Upavedas, the claim regarding their representation of knowledge is true as the books encompass a variety of sciences, psychology, and cosmology. To understand any of the Vedic texts, it is essential to know the Vedic system of knowledge. One common classification of knowledge is in terms of aparā (material) and parā (transcendental). The Saṃhitās and their commentaries are meant to lead to parā knowledge whereas the Vedāṅgas and the Upavedas deal with aparā knowledge.

The Saṃhitās teach through paradox which is presented in tripartite fashion as *trayī vidyā* (e.g. ŚB 5.5.5.6); it is also acknowledged that specific disciplines have their own paradoxes. Speech and language are considered to have four forms (RV 1.164.45), of which one kind, the parā, is unmanifest. In other words, it is acknowledged that language cannot express all aspects of the nature of reality. The Saṃhitās in themselves cannot teach transcendental or unifying knowledge, and they are a ladder that takes the reader into open space where he can fly, and the ladder itself becomes useless.

Several texts mention that the Vedas are eternal or *apauruṣeya.* ŚB 6.1.1.8 speaks of how Prajāpati created the Vedas, *sa brahmaiva prathamamasṛjata trayimeva vidyām.* ŚB 11.5.8 and AB 5.32 have similar passages that speak of how three lights (*jyotis*), Agni, Vāyu, and Āditya, were first produced. Agni was born from the earth, Vāyu from the atmosphere, Āditya from the sky. Ṛgveda was thereafter produced from Agni, Yajurveda from Vāyu, and Sāmaveda from Āditya. From these three pure sounds were born: *bhūḥ* from the Ṛc, *bhuvaḥ* from the Yajus, and *svar* from the Sāman. From these, in turn, come the sounds *a, u,* and *m,* which when taken together form the syllable *om.*

The non-human origin of the Vedas symbolizes the belief that the Vedas express eternal laws that are seen when *tapas* sharpens the consciousness of the ṛṣi and he is able to look at the transcendent self within.

Peter Raster argued that the multitude of phonetic symmetries in the first hymn of the Ṛgveda could not have been consciously designed. Raster restated the doctrine of non-human origin as:[5]

> In this restatement of the doctrine of the impersonal origin of the Veda, the reflection of nature's intelligence in a human mind is understood in a purely formal sense. What is reflected are patterns or modes of functioning, which are common to both, human intelligence and nature's intelligence. Projected onto the surface form of language, these patterns appear as patterns of sound, not of meaning. The search of traces of these patterns in the Vedic hymns, therefore, can largely disregard the meaning which is commonly associated with the Vedic hymns and adopt a formal structural approach.

The theory that the Vedas are non-human implies that the knowledge they represent is eternal, not that the hymns have been in existence for ever. According to another view, Vedic chants and symbols are archetypes of human consciousness, and it is in this sense that Vedic knowledge is eternal.

## Numerical Considerations

Here we speak of the style of writing in the Brāhmaṇas in which many statements are justified in a numerological manner. But this style should not be taken to mean that a deeper understanding was lacking.

Consider, for example, the number 360, the days in the year, which forms a starting point in the design of the altars of ŚB that were used to represent various astronomical facts about the year.

ŚB 10.4.2.1-18 points out that 720, the nights and days in the nominal year, has exactly 15 factors that are smaller than the companion. These divisors are stated to be: 1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 16, 18, 20, 24. The numbers in this sequence which do not divide 720 (that is the numbers 7, 11, 13, 14, 17, 19, 21, 22, 23) are also explicitly mentioned.

The fact that there exist 15 such factors was taken to explain why the moon waxes for 15 days and wanes for 15 days. The next passage claims that 24, the largest of these numbers, represents the number of half months in the year, which is a reiteration of $15 \times 24 = 360$.

This implies the thesis that the moon's circuit around the earth is 30 days because 720, the number of days and nights in the year, has exactly 30 different divisors. In other words, numbers are used to relate a characteristic of the motion of the sun to another related to the moon's orbit around the earth. An astronomical fact is "explained" based on an abstract numerical property.

It appears that the authors did not rather consider the number 360, which has 12 divisors, which could have also been taken to correspond to the 12 months of the year, yielding, in turn, the 30-day duration of the month, because the largest of these divisors which is less than its companion, 18, has no direct correspondence with the basic facts of the year.

The concern with the number of divisors implies finding out what numbers do not have divisors, or are prime. We know, that for number $n = {p_1}^{a_1} \times {p_2}^{a_2}$, the number of divisors $d(n)$ is given by:

$$d(n) = (a_1 + 1)(a_2 + 1)$$

The pairs of these divisors, in the manner of counting by the Vedic authors, is $\delta(n) = d(n)/2$.

The Vedic authors were also interested in the largest divisor, whose companion is smaller than itself. If this divisor is called $\mu(n)$, we have $\mu(720) = 24$.

### The six day Vedic week

One would expect that paralleling a justification of the thirty day month based on the number of factors of 720, an argument would have been used to define divisions of the month. The argument would look at the 60 days and nights of the month and determine the number of divisors that, paralleling the procedure in ŚB, are less than the companion. These divisors are 1, 2, 3, 4, 5, and 6. This suggests a week of six days. We do get references to the six-day week called ṣaḍaha in the Vedic texts. Five ṣaḍahas made a month. This defined a symmetry with the year of five seasons and the yuga of five years.

Although it has often been assumed that the seven-day week was a later innovation, it is quite possible that it was the older tradition and that the six-day week got mentioned in the texts because of the "theory" behind its derivation. The seven-day week is a more natural, system because it divides the lunar month into four equal parts.

The number 7 plays an important number in Vedic cosmology since it appears in conjunction with the name of the entire country, Sapta Sindhu, with the additional ideas of seven rivers, seven continents, seven islands, seven mountains, seven ṛṣis (the Pleiades), seven musical notes, and seven worlds.

### The division of the year into 10,800 muhūrtas

ŚB 10.4.2.36 speaks of the division of the year into 10,800 muhūrtas. It is further stated that the divisors of this number go into 30 arrangements, implying that it has 30 pairs of divisors or $d(10,800) = 60$, or $\delta(10,800) = 30$.

$$d(10,800) = d(2^4 \times 3^3 \times 5^2) = (4+1)(3+1)(2+1) = 60$$

The text further relates the 30 pairs of divisors to the 30 nights of the month.

The calculation of the 30 pairs of divisors of 10,800 suggests that similar calculation was made for other numbers also, increasing our confidence in the belief that the Vedic rishis knew primality.

### Equivalence and Altars

The notion of equivalence (*bandhu*) amongst the *adhidaiva* (*devas* or stars), *adhibhūta* (beings), and *adhyātma* (spirit) plays a central role in the Vedic system of knowledge (e.g. BG 8.1-2). The Vedic altar, *adhiyajña*, shows these equivalences symbolically at different levels including that of the individual himself (BG 8.4). Not only was astronomical knowledge represented in the design of these altars but the designs also mapped characteristics of the individual's inner sky. The astronomy of the altars was tersely spelled out as in the tenth chapter of the Śatapatha Brāhmaṇa entitled *Agnirahasya*. The Ṛgveda itself is viewed as an altar of mantras in the Śulbasūtras (BSS 7.17, ASS 14.11).

Altars were used for two types of Vedic ritual: *Ṣrauta* and *Gṛhya*, which marked specific points in the year or during the day. Two important Soma rituals are agniṣṭoma and agnicayana.[6] The Śatapatha Brāhmaṇa describes the twelve-day agnicayana rite that takes place in a large trapezoidal area, called the mahāvedi, and in a smaller rectangular area to the west of it, which is called the prācīnavaṃśa or prāgvaṃśa. ŚB 10.4.3.9 rasserts that agnicayana represents ritual as well as knowledge.

The mahāvedi trapezium measures 30 prakrama on the west, 24 prakrama on the east, and 36 prakrama lengthwise. The choice of these numbers is related to the sum of these three equalling one fourth the year or 90 days (ŚB 10.2.3.4). The nominal year of 360 days is used to reconcile the discrepancies between the lunar and solar calendars, both of which were used.

In the mahāvedi, a brick altar is built to represent time in the form of a falcon about to take wing, and in the prācīnavaṃśa three fire altars are built in specified positions, the gārhapatya, āhavanīya, and dakṣiṇāgni. The gārhapatya, which is round, is the householder's fire received from the father and transmitted to the descendants. It is a perpetual fire from which other fires are lighted. The dakṣiṇāgni is half-moon shaped; it is also called the anvāhāryapacana where cooking is done. The āhavanīya is square. Between the āhavanīya and the gārhapatya a space of a rough hourglass is dug out and strewn with grass; this is the *vedi* for the gods to sit on (Figure 1.1).

During the agnicayana ritual the old āhavanīya serves the function of the original gārhapatya. This is the reason why their areas are to be identical, although one of them is round and the other square. In addition, eight dhiṣṇya hearths are built on an expanded ritual ground (Figure 1.2).

Agnicayana altars symbolize the universe. The gārhapatya is the earth (ŚB 7.1.1.13), the dhiṣṇya hearths are space (ŚB 7.1.2.12), and the āhavanīya altar, which is made in five layers, is sky (ŚB 8.2.1,2). Since the sky represents the universe, it includes space and earth. The first layer represents the earth, the third the space, and the fifth the sky. The second layer represents the joining of the earth and space, and the fourth layer represents the joining of space and sky. The Śatapatha Brāhmaṇa (10.4.3.9) asserts that knowledge is gained through altar construction.

Time is represented by the bird. The months of the year were ordinarily divided into six seasons unless the image of the bird for the year was used, when hemanta and śiśira were lumped together. The year as a bird had the head as vasanta, the body as hemanta and śiśira, the two wings as śarada and grīṣma, and the tail as varṣā (TB 3.10.4.1, ŚB 10.4.5.2).

The Vedic sacrifice captures the magic of change, and of time in motion. Put differently, the altar ritual symbolizes the paradoxes of separation and unity, belonging and renunciation, and permanence

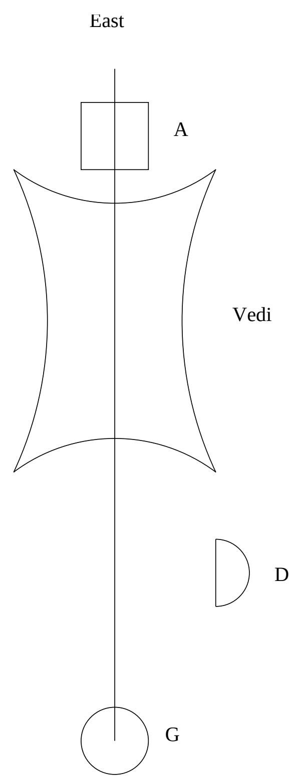



Figure 1.1: The ritual ground

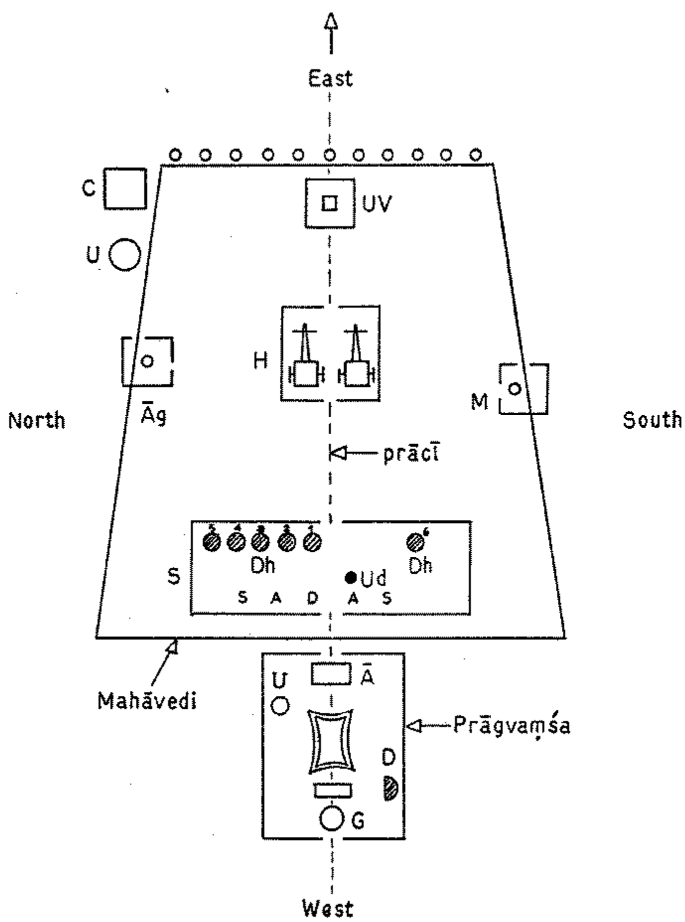



Figure 1.2: The expanded ritual ground. Ā: Āhavanīya; G: Gārhapatya; D: Dakṣiṇāgni; UV: Uttarvedi; Dh: Dhiṣṇya hearths which include Āg: Āgnīdhra and M: Mārjālīya; H: Havirdhāna shed

and death. The yajamāna, the patron at whose expense the ritual is performed, symbolically represents the universe:[7]

> To the Vedic thinker the whole universe was constantly moving between two poles—of birth and death, integration and disintegration, ascension and descent—which by their interaction occasion the cyclic rhythm of the cosmos... All things, entities, notions, powers are connected with each other. Nevertheless, this world is not the chaos it seems at first sight. The point at issue for the Vedic thinker is not to disentangle and differentiate conceptually different entities and notions but to realize, to know, their connections (*bandhu-*). In the course of this process the connections converged more and more and in the end, as is shown in the upaniṣad texts, the intrinsic coherence of the universe was formulated in the ultimate connection *tat tvam asi...* The place of sacrifice is by virtue of the code of connections identical with the cosmos; the three fires are the three divisions of space, the course of the sacrifice represents the year.

The ritual culminates in his ritual rebirth, which signified the regeneration of his universe. In other words, the ritual is a play dealing with paradoxes of life and death enacted for the yajamāna's family and friends. In this play, symbolic deaths of animals and humans, including the yajamāna himself, may be enacted.

### Evolution of Vedic Thought

This development of Vedic ritual is described in the Purāṇas where it is claimed that the three altars were first devised by the king Purūravas. The genealogical lists of the Purāṇas and the epics provide a relative chronology in which to place Purūravas.[8]

An astronomical basis of the Ṛgvedic organization helps us see Vedic ritual in a new light and it shows the inadequacy of earlier interpretations. If Ṛgvedic Indians were good astronomers then the tripartite system of knowledge and its representation using altars represents a subtle approach to reality. The existence of early Vedic astronomy also means that the internal astronomical evidence in the Vedic texts argued by Tilak, and Jacobi and others[9]cannot be ignored. Internal evidence compels the conclusion that the prehistory of the Vedic people in India goes back to the fourth millennium BCE and earlier. Such a conclusion is in consonance with new archaeological discoveries that show a continuity in the Indian tradition going as far back as 8000 BCE.[10]

Recent archaeological findings establish that the Sarasvatī river dried up around 1900 BCE precipitating the collapse of the Harappan civilization which was principally located in the Sarasvatī region. Francfort even argued that the Dṛṣadvatī was already dry before 2600 BCE.[11]The region of the Sarasvatī and the Dṛṣadvatī rivers, called Brahmāvarta, was especially sanctified (e.g. RV 3.23.4) and Sarasvatī was one of the mightiest rivers of the Ṛgveda. This evidence means that many Ṛgvedic hymns are anterior to 1900 BCE and if one accepts Francfort's interpretation of the data on the Dṛṣadvatī then the Ṛgvedic period includes the period before 2600 BCE.

Seidenberg[12] sought the earliest mathematics and geometry in the Śatapatha Brāhmaṇa. The sixth chapter (*kāṇḍa*) of the book provides significant clues. Speaking of creation under the aegis of the Prajāpati (reference either to a star or to abstract time), mention is made of the emergence of Aśva, Rāsabha, Aja and Kūrma before the emergence of the earth. Although some argue that these refer to stars or constellations, the Vedic scholar Viśvanātha Vidyālaṅkāra[13]suggests that these are the sun (Aśva), Gemini (Rāsabha), Aja (Capricorn) and Kūrma (Cassiopeia), indicating that the view of the universe was not centered on the earth.

The Ṛgveda says the universe is infinite. It also refers to the five planets as gods and mentions Bṛhaspati (Jupiter) and Vena (Venus) by name (e.g. RV 4.50.4 and 10.123.1). The moon's path was divided into 27 equal parts, although the moon takes about 27 1/3 days to complete it. Each of these parts is a nakṣatra.

The Taittirīya Saṃhitā (TS 2.3.5.1-3) specifically mentions that the nakṣatras are linked to the moon's path. RV 10.55.3 mentions the 34 lights, which are apparently the sun, the moon, the five planets, and the 27 nakṣatras. A representation of the 12 zodiacal signs, the planets, the sun and the moon in their circuit around the Meru is given in Figure 1.4.

In later literature the list of nakṣatras was increased to 28. Constellations other than the nakṣatras of the path of the moon were also known. RV 1.24.10; 10.14.11; 10.63.10 mention the Ṛkṣas (the Bears), the two divine Dogs (Canis Major and Canis Minor), and the Boat (Argo Navis). The constellation Tiṣya is invoked in RV 10.64.8. But since TS 2.2.10.1-2 says Tiṣya is Rudra, perhaps Sirius is meant. The Aitareya Brāhmaṇa (AB 3.33) speaks of Mṛga

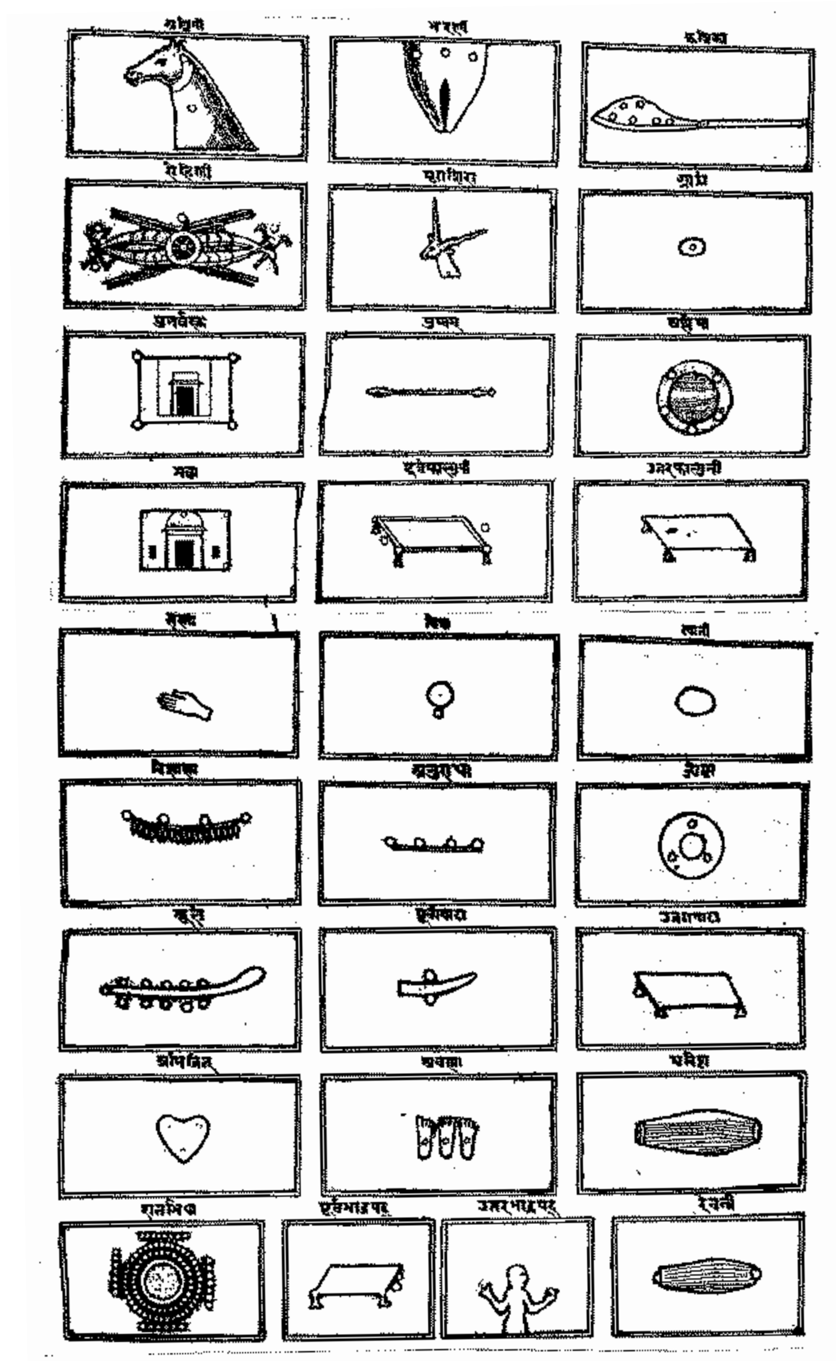


Figure 1.3: The 28 nakṣatras

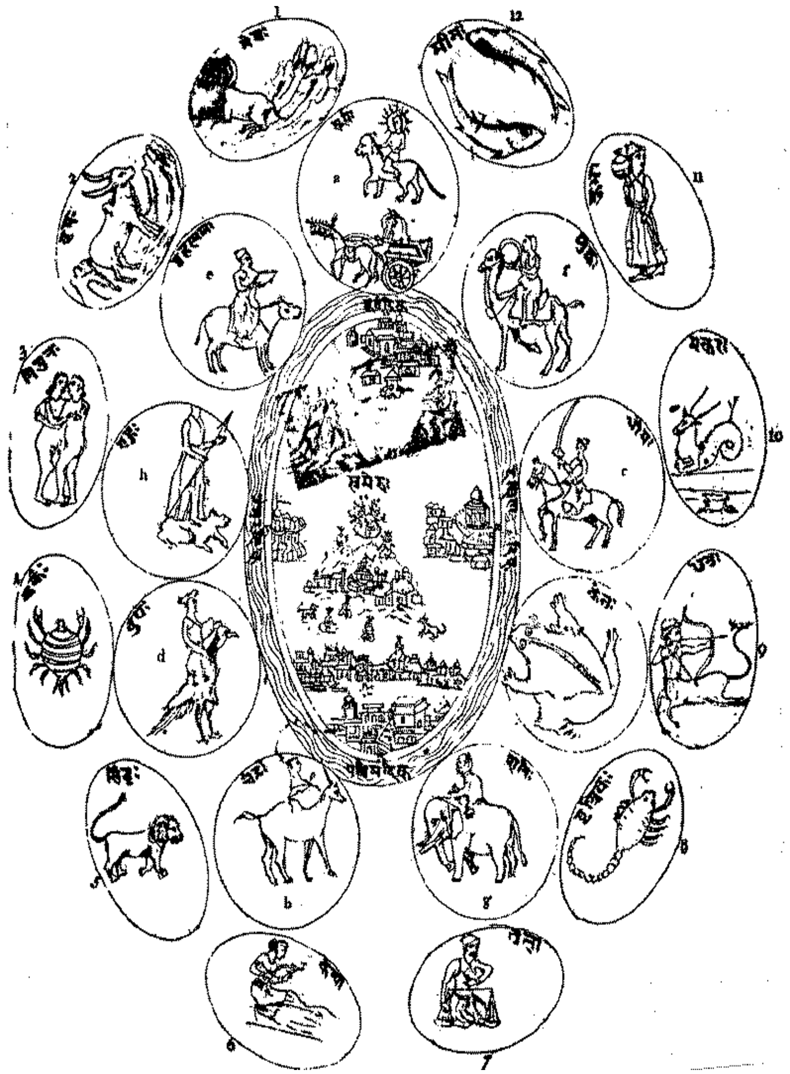


Figure 1.4: The Indian zodiac along with the planets, the sun and the moon

(Orion) and Mṛgavyādha (Sirius). TS 3.4.7 calls the moon sūrya raśmi, one that shines by sunlight.

The lunar or synodic month was measured from full moon to full moon or from new moon to new moon (TS 7.5.6.1), and twelve lunar months constituted the lunar year. The lunar month consisted of 30 lunations (BU 1.5.14). In analogy with a civil day, a lunar day was reckoned by dividing the lunar year into 360 parts called tithis[14] although in practical terms the tithi was determined by a calculation of a 12 degree shift with respect to the sun, and this made the practical measure somewhat non-uniform. The Vedāṅga Jyotiṣa takes a yuga of five years to be equal to 1,830 sidereal days or 62 synodic months or 1,860 tithis. Much later Varāhamihira takes the yuga to contain 1,830 civil days rather than sidereal days.

That different definitions of of the tithi has caused confusion regarding this measure. But there is ample evidence that the slightly different representations of the later texts represent different approximations. Vedic astronomy was not based on the use of accurate clocks, but smaller time units were defined in relation to longer durations. To preserve correspondence between lunar and solar years, intercalary months were inserted at regular intervals (see e.g. RV 1.25.8). Thus the system of Vedic astronomy was based firmly on scientific considerations.

This book considers a variety of questions related to Vedic astronomy. It begins with a review of the context in which the nineteenth century Vedic studies were carried out. Vedic astronomy compels us to ask questions regarding the chronology of the Vedic era which is why we consider Vedic and Purāṇic genealogies and review the date of the Bhārata War. The texts are considered in relation to the recent archaeological evidence. This is followed by a study of the astronomy of the fire altars. After the Ṛgvedic code is described, we analyze the Atharvaveda and the Bhagavadgītā and find their organizations also portray a knowledge of the code. The presence of the code in the Bhagavadgītā demonstrates that it remained known for centuries.

The book also considers the astronomy of the Vedāṅga Jyotiṣa and Purāṇic cosmology. A continuity between early Indian astronomy and Babylonian and Greek views on the universe is shown. The spread of Indian scientific ideas constitutes the last chapter of the book.

# 2. *The Context of Vedic Studies*

## History and Analysis

The Vedic literature provides its own exegesis. The details of the ritual as well as the philosophical basis are found in the Brāhmaṇas, the Āraṇyakas, and the Upaniṣads. Further explanation is provided by the Bṛhaddevatā, the Epics, and the Purāṇas. The Brāhmaṇas, the Nirukta, the Bṛhaddevatā and other texts show how the linguistic perspective informed traditional analysis. A triadic representation is used in a recursive fashion to describe the unity of the fundamental ground substance. The deities are described as belonging to either Agni, Indra, or Sūrya paralleling the division of the physical universe into the earth, the atmosphere, and the sky. That these are mere linguistic devices to describe a unity is clear by assertions such as "In Indra are contained Parjanya, Rudra, Vāyu, Bṛhaspati, Varuṇa, Ka, Mṛtyu, and the god Brahmaṇaspati; Manyu, Viśvakarman, Mitra, Kṣetrapati, Yama, Tārkṣya, as well as Vāstoṣpati, ...., and Agni, Soma, ...." (Bṛhaddevatā 1.122-131).

Yāska's Nirukta is one in a continuous series of commentaries of which Sāyaṇa's 14th century commentary is best known. Yāska speaks of seventeen predecessors with conflicting explanations. One of these predecessors, Kautsa, claimed that Vedic exposition was useless as the Vedic hymns were obscure or mutually contradictory. Yāska and later commentators did not know the astronomical basis of the Vedic system. The past century saw resurgence of interest in Vedic scholarship thanks to the work of Dayānanda Sarasvatī (1824-1883) and Aurobindo Ghose (1872-1950). These scholars presented original yogic interpretations of the hymns which allowed them to see a unity in Vedic knowledge. Their work was useful corrective as it focussed on questions that had been ignored in academic circles.

The analysis in the academic world is informed by philosophical attitudes shaped by ideas in physics and biology. Western academic scholarship on the Vedas was deficient because it was mired in the mechanistic approach of the 19th century, which was later superseded by relativistic and quantum mechanical views that present a holistic view of reality. The older Indian tradition of Vedic analysis appears to be consistent with new ideas in physics as it is based on the notion of an interpenetrating unity. Other aspects of the Vedic system are concerned with information and meaning, again in harmony with newer scientific disciplines.

Western Vedic scholarship is limited by its rejection of Purāṇic data. The work of Dayānanda and the Ārya Samāj school also suffers from this shortcoming and from the literal rendering of the doctrine of the non-human origin of the Vedas.

Nineteenth century Indologists were influenced by certain attitudes that were inimical to the spirit of free inquiry. There were those who wished to fit Vedic chronology within the straitjacket of biblical chronology which colored their interpretations. There were others who saw stages of human evolution at work in the different layers of Vedic literature. Most dismissed the notion of underlying unity because such an idea had not yet arrived in physics. The gods were viewed in anthropomorphic terms. When scientific discourse changed, there was no corresponding revolution in the academic Vedic exegesis.

The nineteenth century academic was preoccupied with classification of phenomena in a naturalistic manner. Although this attitude was fruitful in some fields, its use in Vedic studies did damage to the academic discipline. There was no attempt to find the grammar behind the Vedic view. Lacking this grammar, scholars found contradictions in the texts.

Rudolf Roth (1821-1895), one of the first major European Indologists, would not see anything more than old religious lyrical poetry in the Vedas. A. Kuhn (1812-1881) and Max Müller (1823-1903) sought parallels between Vedic and other Indo-European mythologies, but without a proper understanding of the Vedic system. Abel Bergaigne (1838-1888) saw Vedic gods as anthropomorphic masks for forces of nature, and he found an identity between the cosmic, the ritual, and the moral orders spelt out in the Vedas. Richard Pischel (1849-1908) and Karl Geldner (1852-1929) argued for interpretations within the Indian context, but they saw a primitive nature religion in the system. Hermann Oldenberg (1854-1920) followed an evolutionary approach, as did A.A. Macdonell and A.B. Keith. In recent years the philologist Jan Gonda stressed the need for a thorough reassessment, yet his work remained narrow in its vision. There was no attempt to study the architecture of the Vedic texts.

Some scholars see in the Ṛgveda a sequence of attitudes going back to the most primitive in human origins. Staal[1] hearkens back to the very development of language in his theory that mantras are like bird-songs and they represent the beginnings of language.

The parallels between Vedic and European myths were examined by G. Dumézil who speaks of a tripartite conception of the Indo-European society into priest, warrior, and cultivator reflected in the triad of gods Agni, Indra, and Viśve Devāḥ in India, or Jupiter, Mars, and Quirinus in Rome. Religious and political sovereignty is viewed as a dual category of the jurist-priest (brāhmaṇa, *flamen*) and magician-king (rājā, *rex*). This approach is based on categories of traditional Vedic analysis. Although a useful view, it has not been investigated thoroughly.

Comparative mythology is constrained by the strait-jacket of chronology of the dispersal of the Indo-European people that became popular in the nineteenth century. It was assumed that the Vedic texts represented literature that arose soon after the dispersal from the homeland.

## The Aryan Invasion Myth

We now present a brief review of the controversies about Indian chronology which are a case study in the sociology of rise and fall of paradigms. Max Müller is credited with the popularization of the theory that nomadic hordes of horse-riding Aryans invaded India in mid-second millennium BCE, subjugated the original inhabitants and imposed their culture and language. This theory explained the fact that the languages of North India and Europe belong to the same family and that the myths of the Indian and the European worlds have much commonality. This theory assumed an expansion of the Indo-Europeans into Europe at about the same time as the supposed invasions into India. The epoch of mid-second millennium BCE was based on the evidence that references to Vedic gods dating back to this period exist in Mesopotamia and Turkey. It was assumed that these were the records of the Aryans on their way to India from their original homeland.

While this theory provided an explanation within the framework of the then emerging field of archaeology, it suffered from serious weaknesses. The context in which the word Aryan was used was wrong because this word in the Indian literature refers to culture and not race or linguistic background. It had no explanation for why Vedic literature had no knowledge of regions outside India.

The astronomical references in the Vedic texts allude to events of the third millennium BCE and earlier, and Indian sciences, literature and philosophy were advanced, indicating a long tradition of scholarship. Most importantly, archaeological sites of the Indus, or the more aptly named Sindhu-Sarasvatī tradition, which go back to at about 8000 BCE, show cultural continuity with later Indian civilization. If one could explain the cultural continuity by arguing that the invading Aryans eventually adopted the culture of the original inhabitants, then how is one to explain the fact that they imposed their language?

Amongst other problems with the invasion theory was the fact that the Indo-European populations in the Near East show great stability with regard to location. The regions where inscriptions and texts with Vedic references have been obtained still have Indo-Iranian populations. Wherever there have been movements of people and languages, densely populated regions have maintained their ethnic and cultural continuity. Considering that India was one of the most densely regions before the third millennium BCE, how did the ethnic profile of this vast region changed so late?

More recently the date for horseback riding has been pushed back to earlier than 4000 BCE,[2] so that, even if the questionable assumption of the horse providing the impetus for the expansion of the Indo-Europeans is accepted, it invalidates many of the crucial details of the invasion model.

Once the theory of horse riding invaders took root, any evidence that went against it was ignored or brushed aside as being ambiguous. Questions about the process underlying the hypothesis were not asked. Small bands of invading peoples cannot completely overwhelm the original languages of a huge geographical area without evidence of a break in the archaeological record.

If the invasion was massive, what was the original location of these people, and what made them leave this supposed homeland? What processes were at work that the homeland produced an explosive population growth that compelled its inhabitants to seek fortunes elsewhere in large numbers so as to linguistically conquer a most densely populated region? The proponents, under pressure from conflicting evidence, modified their hypothesis to a form that is unfalsifiable. Thus it is claimed that Indo-Aryans started arriving even before the Harappan civilization, but they came in large numbers only in the second millennium BCE. In another scenario, it is claimed that the Harappans may have been Indo-Aryan but they were pre-Vedic. Some others take it as axiomatic that the Harappan culture is non-Aryan.

What is being negated by the accumulated evidence is not the idea of a homeland but a dispersal taking place in the second millennium BCE. According to one theory the likely era for dispersal is at least 6500 BCE because that seems to be the epoch when farming appeared in India and Europe and the technology and surplus wealth then served as the vehicle that led to the expansion. Prior to that the population density was much lower in both these areas and thus the new group displaced earlier inhabitants. During such an expansion there was intermarriage with the local populations explaining the racial diversity of the Indo-European peoples.

A quick conquest implies take-over by an elite group which does not displace original culture or population. A small population elite ruling a large area, isolated from the culture of its own people, will adopt the culture and the language of the host population. Observe also that prosperity of a region will also draw immigrants from elsewhere. The processes underlying the transfer of culture, language, and race are bound to be more complex and intricate than any simple invasion model presupposes.

The literary, archaeological and other data indicate dispersal of the Indo-Europeans several millennia prior to the mid-second millennium epoch. As for the location of their original homeland, no region from east Europe to northwest India can be excluded on current evidence.

Some have argued that a peculiar complex of intellectual and political attitudes current in Europe was responsible for the ascendancy of the invasion theory. The discovery of ancient Sanskrit literature first led scholars to assume that the regions of the Himalayan ranges was the homeland, which was based primarily on the priority of the Indian literature. In the 1860s, physical anthropology was pressed into service by a new generation of scholars to argue that the original homeland was Europe on the assumption that the authors of the Indian texts were light-skinned blonds. In truth, 19th century European scholars could not conceive of a region outside of Europe to having created a high civilization centuries before their own. There also was the attempt to compress the chronologies of the ancient world within the framework of biblical chronology. There was linguistic error in giving racial connotation to the word Aryan although it had no such implication in Sanskrit.

Some compared the supposed invasion of India with the conquest of the Americas by the Europeans but they did so ignoring fundamental differences between the two. Europe of five hundred years ago was densely populated unlike the steppes of Central Asia thirty five hundred years ago. European expansion was imperial in design impelled by capitalism and missionary zeal which was quite unlike that of the Indo-Aryans. It was forgotten that in regions where the American Indians were densely populated and where they did not suffer genocide the Indian languages and culture have survived. No such pre-Aryan culture is to be found in the valleys of Gaṅgā and Yamunā or the Punjab.

In the past couple of decades, new evidence from archaeology and literary sources has compelled the proponents of the invasion model to modify their assumptions. The continuity between the Harappan and later art and religion is now explained as a wholesale adoption by the Aryans of the previous culture and civilization, in minutest detail with regard to symbols and with words suitably transliterated. This position is similar to that of the believer in "creation science" who claims that God placed on earth at the same time not only man but also the fossil evidence.

In the absence of any archaeological evidence to support it, the theory of invasion of the Aryans is a a myth.[3] The Brāhmī script evolved out of the Indus (or Sarasvatī) script of the third millennium BCE. Research on earliest Indian geometry shows that we must reopen the question of the dating of the sūtra literature. Seidenberg argued[4] that the late dating of Śulbasūtras, and concomitantly the other Sūtra texts, was prompted by the attempt to see Indian geometry as following the rise of Greek geometry. His demonstration that Śatapatha Brāhmaṇa, which is conservatively dated centuries before earliest Greek geometry, itself contains Indian geometry reopens the question.

Geological studies indicate that the Sarasvatī River dried up about the close of the third millennium BCE. This also calls for a revision in the chronology of the Ṛgvedic era, since the Vedic people were settled mainly in the valleys of that river.

The epoch for the influx of the Indo-Europeans into Europe is being pushed back to the sixth millennium BCE. According to one model, their expansion into Europe was a result of the introduction of farming which made it possible for families to be larger resulting in new settlements and intermarriage with the native inhabitants. There are other models of expansion[5] in which the proto-Indo-European era is dated to 4500-2500 BCE. But this model has conflicts with the astronomical evidence from the Indian texts.

Going still further back, research in genetics has led to the view that modern man arose in Africa about 200,000 years ago and from there migrated to India about 90,000 years ago. This research is based on advances in studies of mitochondrial DNA, inherited through the mother, and Y chromosomes, inherited by males from the father. In this view, secondary migrations originated from India about 50,000 years ago and continued in different waves.[6] During a break in glacial activity when deserts turned into grasslands, people headed northwest into the Russian steppes and on into Eastern Europe, as well as northeast through China and over the now submerged Bering Strait into the Americas.

In a variant of this model, called the multiple dispersal model, there were two migrations out of Africa. This model attempts to explain why haplogroup N of mitochondrial DNA is predominant in Europe and why haplogroups M and N are present in Asia. One migration, represented by haplogroup M, was across the Red Sea traveling along the coastal regions to India. Another group of migrants with haplogroup N followed the Nile from East Africa, heading northwards and crossing into Asia through the Sinai. This group then branched in several directions, some moving into Europe and others heading east into Asia. Evidence of the coastal migration is hypothesized to have been destroyed by the rise in sea levels during the Holocene epoch. In another variant model, there was a single migration to India and then to Europe whose small founder population initially expressed both haplogroups M and N but lost haplogroup M through random genetic drift.

There also exists another theory, which is not as popular as the out-of-Africa theory, that holds that humans arose near the beginning of the Pleistocene two million years ago and subsequent evolution has been within a single human species. According to this theory, human species includes archaic forms such as *Homo erectus* and Neanderthals as well as the modern *Homo sapiens sapiens*. It contends that humans evolve through a combination of adaptation and gene flow between the various regions. Its proponents point to fossil and genomic evidence in support for their hypothesis.

History of science and civilizations shows that scientists and scholars rarely abandon an established paradigm even when new evidence compels such an action. Once scientists and scholars invest their career in support of a theory, it becomes a sort of a self-betrayal to abandon it. This explains why many authorities of the day rejected Champollion's decipherment of Egyptian hieroglyphs, or in recent times the decipherment of Mayan writing was rejected by many scholars. Even in scientific theories, where one has the advantage of predictive power, believers in old theories resist the new. Max Planck, one of the founders of quantum physics, claimed that often only death can separate scientists from their pet theories.[7] This is the only explanation one can provide for the reiteration in new books of the invasion model that has no archaeological or textual evidence to support it.

## The Indo-European Context

We begin with a summary of some influential views on the Indo-European problem. The last ice age in Europe ended around 8000 BCE when glaciers started retreating northwards. The earliest farming communities in Europe are to be found in Greece around 6500 BCE and by 3000 BCE most of Europe, excepting the extreme north, was occupied by farming communities that represented different ethnic and linguistic groups. It is argued that copper and bronze metallurgy was established around 4000 BCE and 3000 BCE, respectively. These technology advances led to increased trade and surplus leading to certain communities becoming stronger than others. Around 2000 BCE a kingdom with a literate bureaucracy emerged in Crete. In another five hundred years we see the rise of the Mycenaean civilization of Greece. Iron working on a significant scale is seen in Greece and southeast Europe around 1000 BCE.

With the development of archaeology, pottery types and other cultural complexes were studied as evidence of the expansion of the Indo-Europeans. Gordon Childe in 1926 suggested[8] that proto-Indo-European culture was characterized by graves covered with red ochre and surmounted by a mound or kurgan. This theory was expanded upon by others who claimed that the Indo-Europeans expanded into Europe in the late bronze age aided by the horse-drawn chariot and the war horse. More recently Marija Gimbutas suggested in her kurgan theory[9] that the homogeneous kurgan culture of the Pontic and Volga steppes characterizes the proto-Indo-European culture and that it was widespread in east Europe at the end of the copper age. In this view, proto-Indo-Europeans is assigned the period 4500-2500 BCE.

There are two polar views regarding the spread of culture: the diffusionists maintain that learning leads to the adoption of new ways, whereas migrationists see the movement of people as the key to ancient economic and social change. A third view sees culture expanding by forces that include learning as well as migration. According to Ammerman and Cavalli-Sforza,[10] the spread of farming increased population densities so that the offspring set up new farms intermarrying with the native population absorbing native genes but imposing their language and culture. They argued that such an expansion would have occurred at the rate of about one kilometer a year.

Colin Renfrew suggested[11] that the spread of farming around 6500 BCE was the vehicle that led to the expansion of the Indo-Europeans there. Of the specific technological or social changes outlined above, it is hard to pick any particular one as having greater intrinsic worth unless such a choice is corroborated by other, independent evidence. Analysis of the genetic evidence from the European population shows some correlation of the genes with the spread of farming in a southeast to northwest direction.

The situation of the Indo-Europeans in the east has not been as thoroughly analyzed as the one in the west. Often the scholars who generalized from the European evidence to the Indo-European model had limited understanding of the Indo-Iranian situation. Most linguistic evidence marshaled by these scholars was based on Sanskrit and independent linguistic data from the Prakrit languages was unavailable to them. The use of the Sanskritic evidence is hampered by the assumption that the analysis of this evidence should not be based on Vedic models of knowledge. A reasoned analysis of the Indian evidence allows us to find independent arguments that have a bearing on the general Indo-European question.

Physical anthropology is at the basis of many popular theories regarding the origins of the Indo-Europeans. In a recent review, J.P. Mallory concluded[12] that "[it] has failed, at least so far, to produce substantial support for any particular theory of Indo-European origins." Although Mallory considered origins in Europe, Near East, and Central Asia in his analysis one can add northwest India to this list and his conclusions still hold.[13] New genetics evidence supports the view that the populating of Europe took place from migrations out of northwest India beginning around 40,000 BCE.

## Linguistic Clues to the Early Society

Based on certain assumptions regarding the dispersal of the original Indo-European people, linguists use features of the common vocabulary to construct a picture of their earliest society. The reconstructed Indo-European society was not monolithic in its culture and it incorporated several dialects. The reconstruction of the proto-Indo-European language is based on assumptions regarding dispersal and contact that are negated by recent findings in archaeology. According to the linguist Antoine Meillet:[14] "Even before the separation Indo-European was composed of idioms which were highly differentiated, and that we have no right to view Indo-European as a single language."

The commonality in the vocabulary can nevertheless reveal the common themes in the organization of society and culture. We will take up a few selected areas to suggest sharing of certain fundamental concepts.

But before we do this, we stress the limitations of the linguistic method in which interpretations are made based on isoglosses or similarities in words or structure across languages. But these isoglosses are often incomplete since all the languages have not been exhaustively studied. For example, a hypothesis was advanced regarding the original homeland of the Indo-Europeans taking the postulated word **mori*, "sea" to have been known only in Europe and Ossetic.[15] But this is wrong since these linguists do not know that Kashmiri, an Indo-Aryan language, has precisely the same word in the original meaning of swamp, marsh land, or lake. This cautions us that reconstructions based on language can only be considered tentative unless there exists supporting archaeological and textual evidence.

### Sacrifice

Sacrifice is central to Vedic thought and it implies a rebirth through transcendence. Such a rebirth is possible because the ātman is taken to have the potential to discover all knowledge. Symbolically, this identity, ātman = brahman, is proclaimed in the mahāvākyas of the Upaniṣads. It is because of this central meaning that sacrifice is symbolically represented as the death of the previous self. In Vedic ritual the notion of sacrifice is given powerful symbolic meaning.

The permanent is sought since the living must eventually meet death. In early Vedic ritual, the yajamāna, the patron, was to find his true, pure self by various offerings and the gifts, symbolizing various parts of his body, to the priest. For the priest, therefore, the acceptance of the gifts came with symbolic danger.

In the classical system of ritual, the patron symbolized the universe and he was identified with Prajāpati, the cosmic man. The ritual represented rebirth of the patron as pure and immortal being. Expectedly, the patron underwent a purificatory ceremony before the beginning of the ritual.

In Latin, the word for sacred is "sacer" which, carries not only the meaning of being consecrated to gods but also "affected with ineradicable pollution, worthy of veneration and evoking horror." Due to this background, that the word "sacrifice," which properly means to make sacred (sacrificium) also implies "to put to death."

In Greek, the word "hágios" represents sacredness. The cognate in Sanskrit yaj- which is worship or praise. From yaj also comes yajña or sacrifice, since transcendence is obtained by "praising" or "recognizing" the already existing potential within.

The sacrifice was performed in India as fire ritual where fire or Agni symbolized time and Greeks also had fire ritual. Just as the Indian was enjoined to maintain a sacred fire, the Greeks had the fire of Prytaneia and the Romans that of Vesta.

### The Law

In Sanskrit the concept of order is represented by ṛta which in Iranian is arta. One sees the same root ar- in the Latin ars, artis, "disposition, talent" and in a slightly modified form in ritus, "rite."

The word dharma represents law in terms of "custom or usage" in Sanskrit and this comes from the root dhar-, to hold. Another word for what is established is dhāman, from the root dhā-, "place." In Greek we have thémis which means "foundation."

### Kingship

The Sanskrit rāj-(an) and the Latin rex represent the king. Their feminine are rājñī and rēgīna. Comparing with the Greek verb orégō, which means to "stretch out," one concludes that rāj- originally meant a king who drew the rules. The ancient king was not a tribal leader but rather one who oversaw the enforcement of the law. The Mahābhārata says that the king upholds dharma not of any specific classes but of all classes.

Iran saw empires, and a new word shāhan shāh, king of kings, was coined based on the Iranian analog of Sanskrit kṣatra, "royal power." One may contrast it with the Sanskrit svatava, "powerful by himself, god" that becomes in Persian xudā, or "God," conceived as the holder of absolute power.

### Society

Paralleling the tripartite division of the physical universe into the sky, the atmosphere, and the earth, the universe of society was similarly divided into three parts, and the original three parts expressed the essence of the transcendent, the royal, and the foundational:

*brāhmaṇa*: expresses the transcendent, brahman, or the sky;

*rājanya*: expresses the royal, raj, or the atmosphere;

*vaiśya*: expresses the foundation, viś, the people, or the earth.

The word brāhmaṇa is often mistranslated into priest. As is common knowledge to anyone within the Indic tradition, a brāhmaṇa who performs ritual for others is not considered a "real Brāhmaṇa." Priestly functions are fulfilled by non-brahmin individuals, and communities have their own ritual functionaries.

The Ṛgveda introduced a further category with respect to which the other three categories were defined. The Puruṣasūkta hymn of the Ṛgveda (10.7) speaks of how the first three classes were born from the mouth, arms, and the thighs of the cosmic man and it adds that the śūdra were born from the feet. This addition represents an attempt at obtaining further symmetry. Just as true reality transcends the sky, there is a ground on which the vaiśya reside.

That this change occurred very early is established by the fact that the Iranian society was also divided into four classes that parallel, more or less, the functions of the Vedic classes. Greek tradition also speaks of a four-fold division of the Ionian society into farmers, artisans, priests, and guardians. Plato, no doubt drawing on this tradition, also divided society into four classes. The Iranian and the Greek traditions suggest a time period much after the early Vedic tripartite division.

Georges Dumézil pointed out parallels between the rāj-brahman divide in India and the corresponding rex-flamen divide in Rome. Likewise, there is a parallel between the Indian Gandharvas, mythical fleet beings with horse heads who were musicians, and the Luperci of the Romans. Dumézil represents their roles in the following words:

> They are opposed also in their innermost purpose: flamines and brahmans are the guardians of sacred order, Luperci and Gandharva are the agents of a no less sacred disorder... one is static, regulated, calm; the other is dynamic, free, violent. And it is precisely because of its inherently explosive nature that the latter cannot remain dominant for anything more than a very brief period of time, the time it takes to purify and also to revivify, to "recreate" the former in a single tumultuous irruption of energy.[16]

**Four Circles**

The Iranian tradition speaks of increasing circles of dam-, the family, viś, the clan, zantu, the tribe, and dahyu, the country. Sanskrit has the corresponding dam, viś, and jantu for the first three; however, the Vedas speak of dasyu as the "barbarian enemies." Latin has domus, vīcus, gens for the first three but no notice of the fourth circle. Benveniste[17] suggests that the Iranian dahyu was derived from an eastern Iranian dialect, Khotanese, where daha means "man." When Darius declared himself to be a king of countries he used the term for people from one portion of the empire. The Sanskrit dasyu refers to the northwestern neighbors of the Vedic Aryans with whom they were in conflict.

**Freedom**

The German frei and the English free is cognate with the Sanskrit priya, "dear." The Persian āzād, is like the Sanskrit ājāta, "born of the same stock." The Latin liberi for liberty is like the Sanskrit rudh-, "to grow," suggesting that in a free society institutions and individuals grow and develop. Latin civis for "citizen" is like the Sanskrit seva, "friendly".

The etymology of the word ārya has long been a contentious question. Ārya denotes a cultured person and we saw its opposition to dasyu or dāsa. This is supported by the Hindi word anāṛī, derived from anārya, which means a fool. Benveniste suggests that the correct meaning of the root ari- is one related by way of marriage as in RV 10.28.1 when the daughter-in-law of Indra complains of how one of her ari, the father-in-law, has not come. This primary meaning explains why arya can be sometimes friendly, sometimes hostile since that is a characterization of relatives. This meaning indicates that the Vedic Aryans did not define castes by birth since that would go counter to a community related by marriage.

### Friendship

Perhaps the root mi, to measure, led to the personification of the sun, which measures out the day, as Mitra. Friendship allows one to measure the other and mitra has this other meaning attested from the earliest times. Measurement carries with it the connotation of contract just as the sun carries with it a certain expected motion. This relates to the Latin mūtō, "exchange," which in turn corresponds to the English "mutual."

A related concept is that of trust, and the starting point here is the root dhruva, "firm." Irish druva- represents "solid, firm" and old Slavic druva signifies "wood." Sanskrit dāru, drū is "tree, wood." Trust itself is seen to be derived from the related truōn in Old English.

From trust one can go to its personification in the soldier. In Old English it is dryhten, also meaning "lord." The Gothic word for soldier is ga-drauhts, where the prefix ga- signifies "companionship." Might the name of the Druhyu, an important people in the Vedas and the Purāṇas, be derived similarly? The Druhyu, owing to their enmity with the Pūru, one of the main peoples of the Sapta Saindhava, gave meaning to the Sanskrit word droha, "enmity." According to several Purāṇas, the Druhyus emigrated away from the northwest of India and founded kingdoms in far lands.

The word for belief or credence, crēdō is like the Sanskrit śraddha, "faith."

### Economy

For Sanskrit paśu, animal that includes man, we have the Latin pecū, livestock. The derivation pecūnia however means possessions more than mere livestock. For gift we have dānam in Sanskrit and dōnum in Latin.

The Sanskrit mīḍha- and the Gothic mizdo refer to wage. The Sanskrit ṛṇa and the English "loan" are cognates.

The diverse Indo-European societies carried many concepts of knowledge by a related vocabulary.

## The Astronomical Frame

Myths from diverse cultures have an astronomical basis.[18] Varuṇa, Ouranos (Greece), Tammuz (Sumer and Babylon), Adon (Canaan, Cyprus), Osiris (Egypt), Telipinus-Sharruma (Hittite) may be seen as being fundamentally the same. These gods were born to the great mother goddesses of their cultural fields: Aditi, Ishtar, Astarte, Isis, the Sun goddess of Arinna, Kybele (Attis). These gods were often represented by the night sky. They encode the constellation of Orion and their myths refer to the vernal equinox in it (7th-5th millennium BCE).

The precession of the vernal equinox was noted by transferring Orion's mythology to Taurus and Aries. Thus Tammuz was killed by his hostile brother Sirius, Osiris by his hostile brother Seth (Ursa Major), Tvaṣṭṛ, Dyauspitā, Prajāpati were killed by their youngest son Indra or Rudra (Sirius). Terrible events in ancient myths usually refer to dramatic celestial phenomena, thus providing chronological markers. But to use them as such, without supporting evidence, can mislead for they could have been adopted at a late stage from another culture. The parallels in the myths suggest that interaction between civilizations goes back very far.

In the Purāṇas, the myth of the churning of the ocean, amṛtamanthana, represents, at one level, the shifting of the astronomical frame. Figure 2.1 shows a traditional representation of this story with the gods and the demons, symbolizing the upper and the lower hemispheres of the sky, respectively, at the opposite ends of the earth.

When myths represent astronomical knowledge, the gods symbolize stars or planets. The word deva for god comes from the root *div*, to shine. The dramatic incidents of the myths refer to departure from an expected clockwork of the stars. This departure is a result of the precession of the earth that changes the orientation of the poles slowly. Other layers of stories added over time may have nothing to do with astronomical phenomena but rather express other dimensions of human experience.

The earth's axis of rotation is tipped at an angle of 23 1/2 degrees with respect to the direction of its orbital motion around the sun. This is what causes the change of seasons and the length of the day. The longest and the shortest days, summer and winter solstices, occur roughly near the 21st of June and December, respectively. The date of a solstice may be marked by noting that the sun appears to linger at the same extreme at sunrise and sunset.

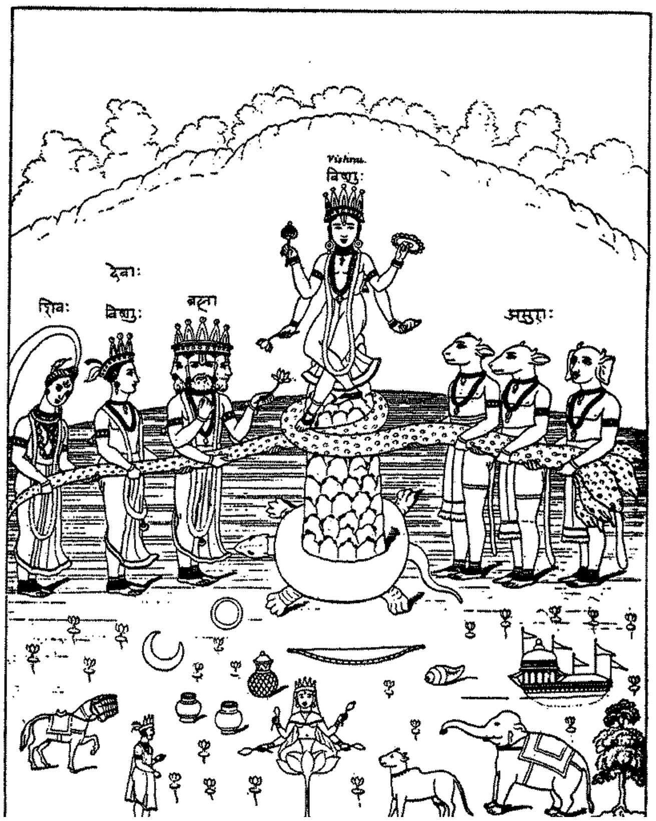



Figure 2.1: The churning of the ocean

The days when the days and nights are equal are the equinoxes. The two equinoxes, vernal in spring and autumnal in fall, mark the halfway points between summer and autumn. The equinoxes occur at the two intersections of the celestial equator and the ecliptic. The motion of the moon is more complex since its orbit is inclined approximately 5 degrees to the earth's orbit around the sun, and the earth's gravitation perturbs the moon in its orbit. The resultant precession completes a cycle in 18.61 years.

The stars present a way to calibrate calendar. Thus some groups of stars dominate the winter nights and others the summer nights. The first or last appearance of a group like the Pleiades would be prominent. Another calibration could be done with respect to a star's heliacal (pre-sunrise, dawn) rising. Thus the heliacal rising of Sirius was important to the Egyptians. During one period of their history, the heliacal rising of Sirius occurred at the same time as the summer solstice and, by coincidence, at the same time as the annual Nile flood. The Egyptian calendar was calibrated, and the year began, with the heliacal rising of Sirius.

Due to the precession of the earth's polar axis, the direction of the north pole with respect to the fixed background stars keeps on changing. The period of this precession is roughly 26,000 years. Polaris ($\alpha$ Ursae Minoris) is the Pole star now but around 3000 BCE it was $\alpha$ Draconis which was followed later by $\beta$ Ursae Minoris; in 14000 CE it will be Vega. The equinoxes and the solstices also shift with respect to the background stars. The equinoxes move along the ecliptic in a direction opposite to the yearly course of the sun (Taurus to Aries to Pisces rather than Pisces to Aries to Taurus and so on).

The vernal equinox marked an important day in the year. The sun's position among the constellations at the vernal equinox was an indication of the state of the precessional cycle. This constellation was noted by its heliacal rising. The equinoctial sun occupies each zodiacal constellation for about 2200 years. Around 5000 BCE it was in Gemini; it has moved since into Taurus, Aries, and is now in Pisces. The sun spends about 13 1/3 days in each nakṣatra, and the precession of the equinoxes takes them across each nakṣatra in about a 1000 years.

The moon returns to a starting position in the zodiac in about 27 1/3 days. Each day was marked by the asterism (nakṣatra) near which the moon was seen resulting in the use of 27 nakṣatras. The Taittirīya Saṃhitā (4.4.10) provides this list together with their presiding deities. The Śatapatha Brāhmaṇa (10.5.4.5) mentions 27 nakṣatras but there was also a tradition of the use of 28 nakṣatras. The Atharvaveda 19.7 lists these 28 together with their presiding deities; the additional nakṣatra is Abhijit. The lists begins with Kṛttikā (Pleiades) where the spring equinox was situated at that time.[19]

Thirteen and a half nakṣatras ending with Viśākhā were situated in the northern hemispheres; these were called devanakṣatras. The remaining nakṣatras ending with Bharaṇī that were in the southern hemisphere were called y*amanakṣatras* (*yama*: twin, dual). This classification in the Taittirīya Brāhmaṇa (1.5.2.7) corresponds to 2300 BCE.[20] The nakṣatra lists of the Classical Siddhāntic period (c. 500 CE) begin with Aśvinī; this implies a shift through two nakṣatras in a total of 28 nakṣatras in use at that time.

The shifting of seasons through the year and the shifting of the northern axis allow us to date several other statements in the texts. Tthe Śatapatha Brāhmaṇa (2.1.2.3) has a statement that points to an earlier epoch where it is stated that Kṛttikā never swerve from the east, which was true for 2950 BCE.

The Maitrayānīya Brāhmaṇa Upaniṣad (6.14) refers to the winter solstice being at the mid-point of the Śraviṣṭhā segment and the summer solstice at the beginning of Maghā, which indicates 1660 BCE. The Vedāṅga Jyotiṣa (Yajur 6-8) mentions that winter solstice was at the beginning of Śraviṣṭhā and the summer solstice at the mid-point of Aśleṣā. This corresponds to about 1300 BCE.

In each one of the above cases, it is assumed that the identification of the nakṣatras is the same as is taken now. This is a reasonable assumption as the nakṣatras are defined by their unique shapes. There could be variation with regard to the consideration of the beginning or the ending segments of the nakṣatras, but this would only change the dates by a couple of centuries in either direction.

Greek notices indicate that Purāṇic king lists were in existence in the fourth century BCE. From the Purāṇic genealogies we have the testimony that the first compilation of the Purāṇas took place at the end of the Bhārata War. Many Purāṇic myths have an astronomical basis and their grammar was passed to the later redactors of the Gupta age.

Sengupta[21] analyzed the textual references in the Vedic and the epic literature and he provides strong support for the dates mentioned above and other dates. It is significant that these dates are consistent with the textual evidence and with the tradition and, as we shall see, supported by new archaeological evidence.

# 3. Chronology of the Vedic Texts

## The Archaeological Context

The setting for the hymns of the Ṛgveda is the area of Sapta Saindhava, the region of north India bounded by the Sindh (or Sindhu) and the Gaṅgā rivers, although regions around this heartland are also mentioned. There are geographical references in the Ṛgveda that are of chronological value. In the past ten millennia north India has undergone major tectonic and hydrological upheavals, and so it becomes possible to correlate geographical references to particular time epochs. Other significant references are to sea-going vessels and to settlements on the Sarasvatī. The archaeological record suggests that this river turned dry around 1900 BCE.

The genealogies of the Purāṇas and later Vedic literature reach back at least into the third or the fourth millennia BCE. The Purāṇas list ninety four generations of kings before the Bhārata War. Later Vedic literature, starting with the Śatapatha Brāhmaṇa, indicates a change in the focus of the civilization outside the original area of the Sindh and the Sarasvatī valleys.

The king-lists of the Purāṇas speak of a catastrophic war—the Bhārata War—in 1924 BCE (or somewhat later), although another tradition places this war over a thousand years earlier. If the Purāṇic tradition is correct then could the War have symbolized the catastrophic tectonic event that dried up the Sarasvatī?

Archaeological investigations show that the Sindhu-Sarasvatī cultural tradition represents the beginnings of the Indian civilization. This tradition has been traced back to about 8000 BCE in remains uncovered in Mehrgarh and other sites.[1] It reached its flowering in the period 2600-1900 BCE in which several cities and towns were established and writing was used. From evidence obtained in recent digs, the beginning of this writing has been pushed back to 3500 BCE.

In the 1970s, it was found that most of the towns and settlements were on the banks of the Sarasvatī river. Hydrological changes and the socio-economic evolution of the groups led to an abandonment of large areas of the Sindh valley. The Harappan phase goes through various stages of decline during the second millennium BCE. A second urbanization began in the Gaṅgā-Yamunā valleys around 900 BCE. The earliest surviving records of this culture are in Brāhmī script.

This second urbanization is generally seen at the end of the Painted Gray Ware (PGW) phase (1200- 800 BCE) and with the use of the Northern Black Polished Ware (NBP) pottery. Late Harappan was partially contemporary with the PGW phase. In other words, a continuous series of cultural developments link the two early urbanizations of India.

The restructuring of society that occurred between the two urbanizations is partially mirrored in the restructuring of the Indus or the Sindhu-Sarasvatī script. The Brāhmī script, which was in use throughout India during the Mauryas, was highly systematic, reflecting the theories of Indian grammarians. Earliest example of this writing goes back to 450 BCE in Sri Lanka suggesting that it was widely used across the sub-continent.

Literary evidence and signs on early punch-marked coins suggest that writing in India during the second urbanization is definitely much earlier than the middle of the first millennium BCE. The punch-marked coins of the seventh century BCE[2] use a Harappan weight standard. It appears that the coins were originally issued as silver blanks by traders and the weights checked by traders. The checking was represented by marks that are strikingly similar to the Harappan signs. By the sixth century BCE, kings began putting their own issuing marks on the coins. These pictorial marks were generally representative of the meaning of the king's name.

The Sarasvatī script uses many more signs than Brāhmī and it is generally written from right to left, in a direction opposite to that of Brāhmī. There are instances of both the scripts being written in the *boustrophedon* style, that is, written in opposite directions in alternate lines. The change in the normal direction of writing indicates a fundamental shift. Whether this shift took place between the two urbanizations or just prior to the Mauryan empire is not clear.

The spread of Indian culture, as indicated by the literary and the archaeological records, may further be checked by an analysis of the processes that supported this spread. Ammerman and Cavalli-Sforza[3] argue for the parallel situation in Europe in that the spread there of farming after 7000 BCE is best seen as a diffusionary process brought about by a combination of cultural diffusion, population growth and displacement, which they call *demic* diffusion. Sokal, Oden, and Wilson[4] published genetic evidence supporting this model. Genetic variation across the Indian subcontinent suggests that a diffusion model was at the basis of the spread of the Indian people as well.

The evolution and restructuring of the ethnic groups is seen in the archaeological record. No evidence for any break in the Indian tradition due to any invasions has been found, and neither is there any evidence of a break in the skeletal record after 8000 BCE. Since the Indo-Aryans were the dominant group in northern India by the late 2nd millennium BCE, one is compelled to the conclusion that they were one of the ethnic groups in the Sindh and the Sarasvatī valley areas as early as 8000 BCE.

There is convergence in the archaeological evidence about the Sindhu-Sarasvatī tradition and the literary and the geographical evidence of the Vedic literature to conclude that this tradition was essentially Indo-Aryan although this conclusion is contested by some linguists. Nevertheless, it is very likely that several languages, some of them non-Indo-Aryan, were present in the area. That the Indo-Aryans represented the Harappan ethnic group is supported by new analysis of the Harappan script which indicates that it was used for an Indo-Aryan language. It is also supported by the geographical evidence from the Vedic literature.

## Evolution of the Tradition

In its earliest phase the Sindhu-Sarasvatī tradition was characterized by cultivation and animal husbandry. Cattle pastoralism was an extremely important component of the economy. It is estimated that as early as 5500 BCE domesticated cattle were already central to food production. In this respect the Sindhu-Sarasvatī tradition is different from the tradition of Mesopotamia which emphasized domesticated sheep and goats. Jim Shaffer[5] views the evolution of the culture in the Sindh region in four broad eras.

The first is the *early food producing era* (c. 6500- 5000 BCE) that is characterized by an absence of ceramics. The next is the *regionalization era* ( 5000- 2600 BCE) in which distinct artifact styles (including ceramics) develop regionally. The third is the *integration era* ( 2600- 1900 BCE) in which we see pronounced cultural homogeneity and the development of urban centers. The fourth era is that of *localization* ( 1900- 1300 BCE) in which characteristic patterns from the integration era are blended with regional ceramic styles. This last era indicates decentralization and restructuring of the interaction networks (Figure 3.1).

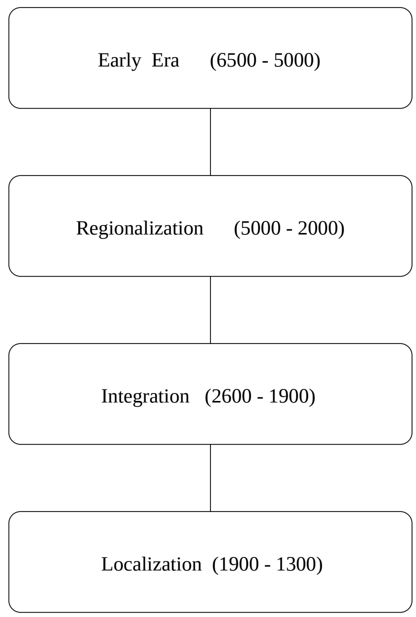



Figure 3.1: Evolution of the Sindhu-Sarasvatī tradition according to Shaffer

S.P. Gupta divided the Harappan phase itself into three periods: (i) *early* (3100 BCE - 2800 BCE); (ii) *mature* (2800 BCE - 1900 BCE); and *late* (1900 BCE - 1400 BCE) based on corrected radiocarbon dates.[6] This classification scheme makes the integration era, characterized by a uniformity in style, much longer than the Shaffer scheme.

Amongst the factors at the basis of the evolution of this tradition, changes in farming are considered to be quite important. According to Richard Meadow:[7] "Two distinct agricultural revolutions can be identified for the northwestern region of South Asia during the pre- and protohistoric period. The first involved the establishment by the sixth millennium B.C. of a farming complex based principally on the *rabi* (winter sown, spring harvested) crops of wheat and barley... The second saw the addition by the early second millennium B.C. of *kharif* (summer sown, fall harvested) cereals including sorghum, various millets, and rice."

In the arid and semi-arid areas of this tradition, buildings were made of mud bricks and fired bricks and stone, and it is likely that wood structures were used in regions where wood was easily available. There was public architecture as in plazas, streets, public buildings, wells, drains, and tanks. Pottery was mass produced by the use of wheels and sometimes by molds. Painted decorations used a variety of geometric, animal, and floral motifs which remain popular in India. A network of long distance trade existed within the region and with the West. Turquoise from central Asia, lapis lazuli from northern Afghanistan, and shells from the coast of the Arabian sea have been found at Mehrgarh. Figure 3.2 presents a map of India for the general period of 3500 - 2000 BCE.

The Sindhu-Sarasvatī tradition consists of several styles, that probably represent different ethnic groups. The richest period of this tradition is named Harappan after the site where the first excavations were made. Soon after that the major site of Mohenjo-Daro was discovered. Since then other major sites at Dholavira, Ganweriwala, Kalibangan, Lothal and Rakhigarhi as well close to 2500 smaller settlements have been discovered.

The Harappan world covered an area of a million square kilometers that stretches from the Himalayas in the north to the Tapti river in the south, and from the Sindh river valleys in the west to the plains of the Gaṅgā and Yamunā rivers in the east. According to a recent estimate[8] nearly two-thirds of the sites are along the Sarasvatī river and a majority of the remaining one-third of the sites are located in Gujarat and Uttar Pradesh; the Sindh valley proper has less than 100 sites.

A temporal pattern underlying the settlements is also clear. Sindh and Sarasvatī valleys, Kutch, and parts of Saurashtra were the focus of the early and mature Harappan settlements, whereas the upper course of Satluj, trans-Yamunā region of Uttar Pradesh, and Saurashtra were the focus of the post-Harappan settlements.

While the Harappan city seemed to evolve out of an irregular net plan, it had two distinctive elements. In many cases, to the west lay a "citadel" on a high platform that housed public and ceremonial buildings. To the east was the lower city with straight and wide main streets that divided the city into large blocks. The blocks in turn were served by narrow curving lanes. The houses were built of generally standardized burnt bricks. They were planned as several rooms around a square courtyard, and were often of two or

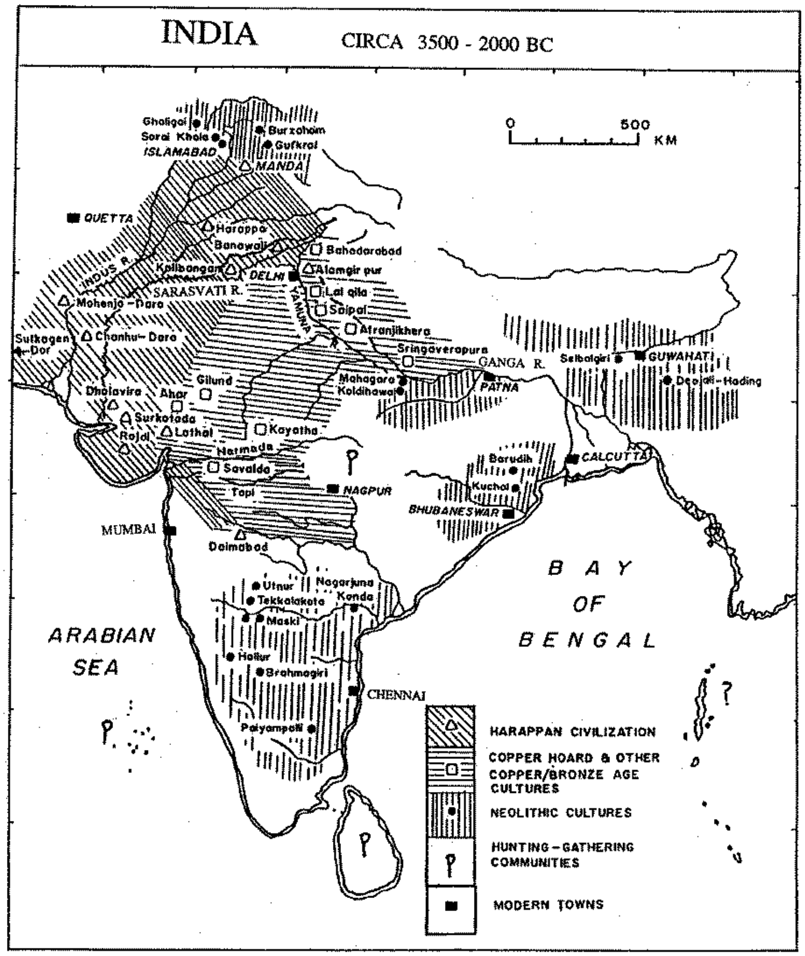



Figure 3.2: India during 3500-2000 BCE

more stories. Some houses had bathrooms which were connected by bricklined drains to sewers under the main streets. Many windows were screened with grilles of terra cotta or alabaster. Houses presented blank walls to the streets and, in many cases, the doors opened on the side lanes in a manner that would not be out of place in a traditional city in contemporary Punjab.

One of the striking buildings in the citadel at Mohenjo-Daro is the great bath. The oblong bath is 39 feet long, 23 feet wide, and 8 feet deep. It was sunk into the paving of a courtyard and it was approached from the north and south by brick steps with possible wooden stair-treads. The floor of the bath sloped to an outlet that led in turn to an arched drain deep enough for a man to stand upright. Just north of the pool were eight small bathrooms drained by little runnels in the floor. Each bathroom had its own staircase leading to the second storey which may have housed cells for the priests, if the whole complex was like the tank of a Hindu temple.

The largest building uncovered at Mohenjo-Daro was probably a palace of size 230 feet long and 78 feet wide. At Harappa a building twice this size, which may have served as a granary, has been discovered. It is significant that the dimensions of these monuments are in units that are related to each other. If the dimensions of the bath are in the proportion 1 : 1.7, that of the palace are 10 : 3.4. The relationship between the sides suggests a normative approach to architecture reminiscent of Vedic architecture. This conclusion is reinforced by the directional symmetries in the buildings.

Recent studies haves shown that the unit of *dhanus* was used consistently in India in town planning and architecture for over 4,000 years, going back to the Harappan period. By considering the largest measure which leads to integer dimensions for the various parts of the Harappan age city of Dholavira, which was excavated in the 1990s , it is found that this measure is the same as the Arthaśāstra (300 BCE) measure of *dhanus* (bow) that equals 108 aṅgulas (fingers).

The measure of *dhanus* is seen to apply not only to the Mauryan and Gupta era structures, but even to more recent grid and modular measures in the town planning of Kathmandu Valley. The measures used in ancient India are summarized below:

1 aṅgula = 1.763 cm
1 vitasti = 12 aṅgulas = 21.156 cm
1 pāda= 14 aṅgulas = 24.682 cm

1 dhanus = 108 aṅgulas = 190.404 cm

With the measure of *dhanus* (D) of 1.9404 m, the dimensions of Mohenjo-Daro's acropolis turn out to be 210 × 105 D; Kalibangan's acropolis turn out to be 126 × 63 D. The dimensions of the lower town of Dholavira are 405 × 324 D; the width of the middle town is 180 D; and the inner dimensions of the castle are 60 × 48 D. The sum of the width and length of the lower town comes to 729, which is astronomically significant since it is 27 × 27, and the width 324 equals the nākṣatra year 27 × 12.

There is a distinct difference in the brickmaking of the two urbanizations. The Harappans used several brick sizes of which the most common had length, breadth, thickness ratios of about 4:2:1. The bricks used during the second urbanization of the Gaṅgā valley are not according to these ratios, one type encountered there has the ratios 7:4:1. But this departure may merely be a result of the popularization of one of the existing styles in a multi-ethnic and multi-cultural society. We do not observe a complete break with the earlier tradition, but only reorganization and re-adjustment. Thus corbelled drains, characteristic of the Harappans, persist in Gaṅgā valley.

The Harappan settlements along the Sarasvatī were located on the desert scarp above the entrenched river. The settlements during the age of Painted Grey Ware (1200-800 BCE) are found within the entrenchment on the bed of the river.[9] This establishes two important chronological markers: first, the river dried up before the PGW era; and, second, the Ṛgveda, which describes the Sarasvatī river as one of the largest of its times, is prior to the drying up of Sarasvatī. Recent satellite remote sensing has shown that the river was as wide as 8 kilometers at places.[10] There are reasons to assume that the abandonment of the Harappan sites in the Sarasvatī valley region was caused by this drying up, and it indicates the epoch of 1900 BCE for this change.

To see the continuity between Harappan and historical architecture, note that the Somapura Mahāvihāra of Pāhārpur has dimensions of 280×281 m, which when converted to *dhanus* become nearly 147×147 D, or 49×49 with the units of three times *dhanus*, which would be a natural plan for a vāstupuruṣamaṇḍala. The base of the temple was generally in a square grid of 8 or 9 units (64 or 81 squares) in the Bdrhat Saṃhitā, but according to other texts it could range from one to 1024 square divisions. The Vaikhānasāgama gives special importance to the 7×7 plan.

The Brihadīśvara temple (which was completed in 1010 CE), has a sanctum tower of 30.2×30.2×66 and it is within an enclosure of 240×120 m. In *dhanus* units, this amounts to 16×16 D plan in an enclosure of 126×63 D, where the error is less than one percent in the sanctum and almost zero for the enclosure. This indicates that the sanctum used a vāstupuruṣamaṇḍala of 64 squares where each square had a length of one-fourth *dhanus*.

### The Vedic House

We consider the Vedic house to get an idea of life in the Vedic times. The Ṛgveda speaks of settled space as grāma in opposition to the forest as araṇya (RV 10.90). But within the grāma could be a fort or high town (*pur*). The *pur* made of stone is mentioned in RV 4.30.20. The place of residence of the individual or joint family was gṛha, and grāma was a collection of gṛhas. The devatā presiding over each house was called Vāstoṣpati. Different names are used for a dwelling and this indicates a wide variety of styles and sizes.

An ordinary house with roof was *chardis* (RV 6.15.3); a mansion was called *harmyam*, which would have several rooms in which lived the extended family incluing parents, many women, and even a guard dog at the door (RV 1.166.4, 7.55.6, 10.55.6); and a multi-residence complex, together with halls for animals, was called *gotra*. The description of *harmyam* suggests that it had an open courtyard in the middle and quarters for women at the back. To consider the poetic description of a dwelling, we look at RV 7.55, addressed to Vāstoṣpati that refers to a house which is substantial, where several families reside and which has a dog guarding it.

One may also look at the question of the residence from the point of view of complexity. The Vedic society had many specialized professions, as evidenced from the Yajurveda 30, the Puruṣamedha hymn, which lists them. The professions include dancer, courtier, comedian, judge, wainwright, carpenter, potter, craftsman, jeweler, bowmaker, ropemaker, dog-rearer, gambler, hunter, fisherman, physician, astronomer (naksatra-darśā), philosopher, moral law questioner.

Further are listed elephant-keeper, horse-keeper, cowherd, shepherd, goatherd, ploughman, distiller, watchman, and the wealthy. Further still, wood-gatherer, wood-carver, water-sprinkler, washerwoman, dyer, servant, courier, snob, pharmacist, fisherman, tank-keeper, cleaner of river-beds, boatman, goldsmith, merchant, and rhetorician; cow-slaughterer, speaker, lute-player, forest-guard, flutist; prostitute, watchman, musician, hand-clapper. A listing of such diverse professions can only reflect a corresponding complexity in social organization, which would be characterized by different kinds of dwellings.

Two hymns from the Atharvaveda refer to the house as a building. AV 3.12 is a hymn meant to mark the starting of the construction of the house, whereas 9.3 concerns the gifting of the structure built for the ritual to the priest. This latter hymn has been cause of much misunderstanding amongst scholars who are not familiar with the actual practice of ritual, who have taken such a temporary structure to be the prototype of the house in the Vedic village.

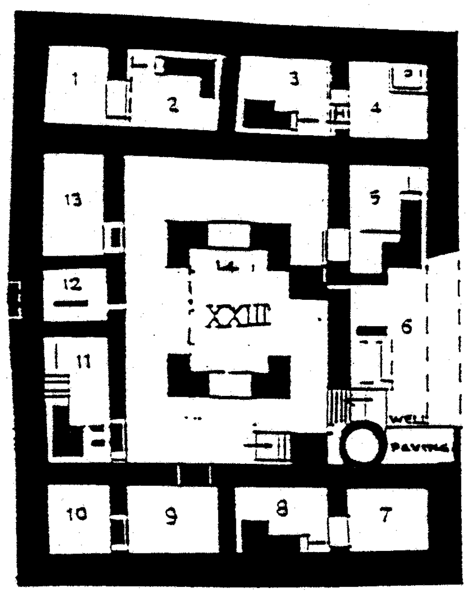
In Atharvaveda 9.3, there is mention of how the house could be of many sizes, with two, four, six, eight, or ten wings (9.3.21). The dwelling is said to be built by the poets, *kavi* (9.3.19), indicating high regard in the society for both builders and designers. The house is said to be the home of Soma (9.3.19); it adjusts itself to all just like a new bride adjusts to the members of the family. The house consecration ceremony described in this hymn is similar to the one done even today in Hindu families on entering a new home.

### Fire Altars

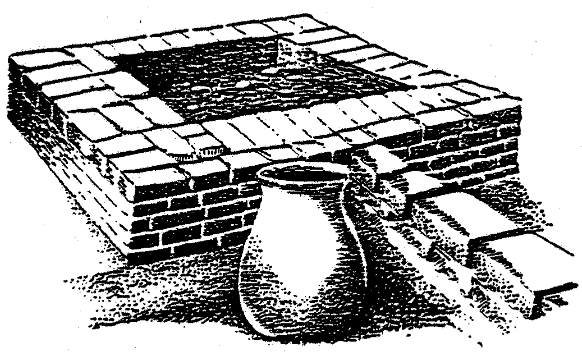
Ceremonial structures that appear to be fire altars have been found in Lothal and Kalibangan.[11] A brick-lined fire pit at Kalibangan has five layers of bricks in the style of the Vedic altar. A platform in the citadel at Kalibangan has seven fire altars in a north-south row, which parallels the six Vedic dhiṣṇya hearths that are placed in the same directional orientation, the seventh hearth could be one of the additional hearths of the Vedic ritual where utensils are cleaned.

It appears that the sites that were excavated earlier were not properly investigated for the presence of fire altars. Nevertheless, by a review of the published records, a significant building at Mohenjo-Daro has been identified by Dhavalikar and Atre[12] as a fire temple (Figure 3.3). The building is 62 feet long and 50 feet wide; it has a central courtyard and a symmetric arrangement of rooms. Every alternate room has a low brick platform and one of the rooms has a staircase leading to an upper floor. It appears that a fire altar was placed in the central courtyard.

This fire temple has symmetric features that have much commonality with the architectural maṇḍalas discovered[13] in North




(i)



(ii)

Figure 3.3: (i) The fire temple in Mohenjo-Daro, (ii) Fire altar at Lothal

Afghanistan dating to 2000 BCE and shown in Figure 3.4. Since textual evidence suggests that such maṇḍalas came to be employed much after the Ṛgvedic age, this evidence provides a useful chronological marker. Apart from the textual evidence one would expect that an artistic representation of the abstract yantric concept would take centuries to develop. Since such buildings have not been found in India, one would assume that this region was under the influence of a priesthood at this time.

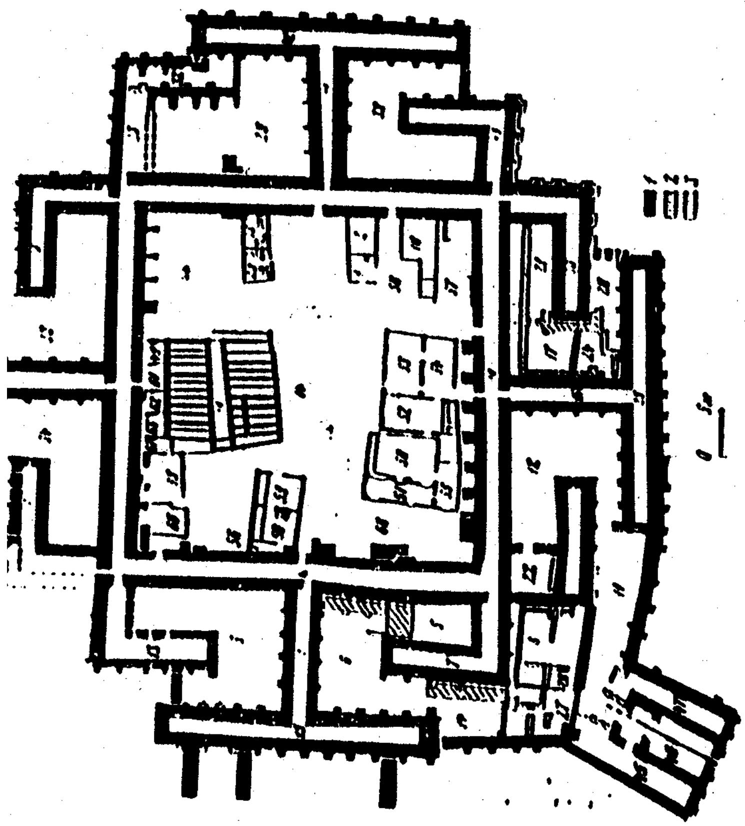


Figure 3.4: The yantric palace at Dashli-3 in North Afghanistan c. 2000 BCE

Another view of the Dashli palace in given below in Figure 3.5.

Other buildings, inspired likewise by abstract notions, were found in the same area.

Another monumental complex excavated at Dashli is round, with nine spoke-like extensions jutting out of the periphery. Within this area are rectangular quarters as well as altar-hearths mounted on brick platforms. The nine spokes (or openings) recall the image of the body with nine openings used often in Indic literature. This complex is in turn surrounded by other buildings with two other concentric circular walls. If such fortress structures represent the *tisraḥ puraḥ* of the dasyus, then we again have support for the notion that the dasyus represent Āryans of Northeast Iran.

### Harappan Writing

I have proposed that the writing of the Harappan era, which is generally called Indus writing, be properly named *Sarasvatī* writing.[14] Sarasvatī is connected in the Indian tradition with writing and learning; furthermore, the Harappan settlements where the earliest writing was used were based primarily along the Sarasvatī river. In later mythology Sarasvatī is remembered as the wife of Brahmā, or as Brāhmī, representing thereby the transformation in the script.

The writing of the Harappans has survived in carvings on seals, small pieces of soft stone, and copper tablets. The total number of inscribed objects is around 4,200, but many of these are duplicates.[15] It should be remembered that many of the large Harappan towns have not been excavated and therefore it is certain that the number of written records in the Sarasvatī writing will go up in the future. The number of different signs used is close to 400, but these include various numeral signs as well as the conjuncts of the more basic signs.

Most texts are very brief, the average length being 5 signs, and the longest text, on a three-sided amulet, is 26 signs long. The longest inscription on a single side is 17 signs, in three lines, on a seal. The primary purpose of the seals was perhaps to mark ownership and the copper tablets may have served as amulets. A large number of seal impressions on clay have survived. These are likely to have served as tags which were attached to bales of goods, for the reverse sides often show traces of packing materials. The impressions of the seals most likely served as signatures. The pictorial motifs that accompany the writing include the humped bull, buffalo, elephant, tiger, rhino, crocodile, antelope, fish, tortoise,

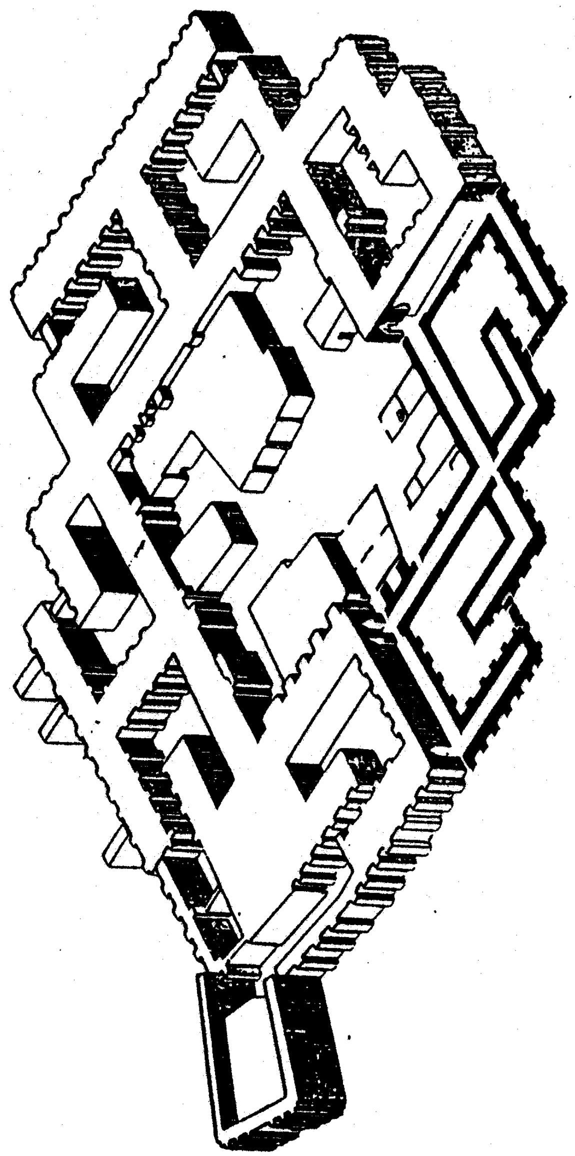


Figure 3.5: Another view of the Dashli palace

and so on. Geometric designs include the svastika, spoked wheel, and a circle with a dot. These pictures are similar to the ones that show up in the seals of two thousand years later.

Signs of extensive trade between the world of the Sindhu-Sarasvatī tradition and central and west Asian regions have been found. The Harappans did maritime trading, and their seals were recovered in Mesopotamia from the 24th century BCE onwards. Conversely, Persian Gulf seals were found in the Harappan port of Lothal. Inland, the Harappans moved their goods using wheeled carts, camels, and boats.

They used strikingly accurate weights in a series that is preserved in later Indian weights. The same unique series is also found on the island of Bahrain in the Persian Gulf suggesting this was their colony. Some weights are so tiny that they could have been used by jewelers to measure gold, others are so big that they must have been hoisted by ropes. Their products included fine pottery wares, jewelry, copper and bronze vessels, and woven cotton goods. The variety and extent of this trade indicates that credit-keeping and calculations were important to the Harappans. The length measurements were also preserved in the later Indian length measures.

Pran Nath noted the striking similarities in the iconography of the Harappan seals and the punch-marked coins of the first millennium BCE.[16] Another parallel is that the seals of the historical period, from the time of Ashoka and later, carry brief texts like the Sindhu-Sarasvatī seals. In almost all cases the legends on the historical seals end in the genitive case, representing ownership. The exceptions are where no case-ending is used, or where the ending is nominative as in religious formulae. The impressions from these seals, like the earlier seals of the Harappan period, authenticated records, or served as signatures.

An analysis of Sarasvatī and Brāhmī writing reveals obvious connections between the two scripts that could not have arisen out of chance.[17] My analysis showed that the most frequent letters of Sarasvatī and Brāhmī looked almost identical and besides they were in the same order of frequency. A probabilistic analysis confirmed the connection between the two scripts. The transformation of Sarasvatī into Brāhmī occurred with changes in the orientations of some signs.

For example the fish sign was flipped over. Similar modifications occurred in the evolution of Brāhmī to the later Devanāgarī, where many signs have been turned sideways or upside-down. The genitive case-ending in Sanskrit is often *sya* or *sa* and in Prakrit the ending is generally *sa* or *ssa* and this is also true of the Sarasvatī inscriptions. This suggests that the Sarasvatī language is likely to have been Prakritic. The sign values for the case-endings were obtained independently through frequency considerations. Further checks were obtained in the readings of some specific signs.

To summarize the connections between Sarasvatī and Brāhmī, note that both scripts use conjuncts where signs are combined to represent compound vowels and that the core set of most frequent Sarasvatī signs seems to have survived without much change in shape into Brāhmī where it corresponds to the most frequent sounds of Sanskrit. The writing of numerals in Sarasvatī, especially the signs for 5 and 10, have carried over to Brāhmī.

The pottery marks in late second millennium BCE are reminiscent of the Sarasvatī signs,[18] as are the signs on the punch-marked coins a millennium later. Additional evidence of cultural continuity indicates that the language of the Harappans was Indo-Aryan.[19] The relationship between Sarasvatī and Brāhmī is evidence that interlocks with other similar evidence from archaeology and literature linking the Harappan and Gaṅgā civilizations. Despite this strong evidence, the theory of the relationship between the two scripts remains the minority view amongst scholars at this time.

## Vedic History

The vast Vedic literature may be analyzed in its own terms by considering its various layers.[20] Vedic books, which include the Saṃhitās and the Brāhmaṇas, mention names of kings in an incidental fashion, but they do provide the genealogies of ṛṣis. Vedic books have been preserved with astonishing accuracy and a tradition has preserved the names of the authors of hymns or verses when a hymn has multiple authors. But not all the famous kings of the Ṛgvedic age, which are mentioned in the Purāṇas, are lauded in the hymns.

Conversely, bards or *sūtas* of the Purāṇas and the epics preserved genealogies of kings and seers. "As seen by good people in the ancient times the *sūta*'s duty was to preserve the genealogies of gods, *ṛṣis* and glorious kings and the traditions of great men." (Vāyu P. 1. 31-2) According to the epics and the Purāṇas (e.g. Mahābhārata 1.63.2417, Vāyu P. 60. 11-12) the arranger of the Vedas was Parāśara's son Kṛṣṇa Dvaipāyana Vyāsa who lived at the time of the Bhārata battle.

The most famous historical event mentioned in the Ṛgveda is the battle of the ten kings, Daśarājña, mentioned in four hymns of the seventh book of the Ṛgveda (18, 19, 33, 83). The battle took place between Sudās, the Tṛtsu king, and a confederacy of ten peoples that include Pakthas, Bhālānas, Alinas, Śivas, Viṣāṇins. It was argued by Talageri[21] that the others were Śimyus, Bhṛgus, Druhyus, Pṛthus and Parśus. After his defeat, the Druhyu prince Sucetas, son of Pracetas, migrated westward and founded kingdoms in far lands, so is claimed by the Purāṇas.

According to the indices, one of the hymns of the Ṛgveda (10.98) is composed by Devāpi and this hymn mentions Śantanu, Bhıṣma's father. This appears to be the youngest hymn in the Ṛgveda and thus the reference is supportive of the Indian tradition. The Yajurveda does not mention anyone later than Dhṛtarāṣṭra and the Atharvaveda mentions a Parīkṣit ruling over the Kurus. There is no mention of Purāṇic kings who came after the Bhārata battle in the Vedic Saṃhitās.

Although the Purāṇas have suffered extensive revisions, the core Purāṇa is dated to the Vedic times. The Atharvaveda (11.7.24) mentions Purāṇa along with the three other Vedas. The Śatapatha Brāhmaṇa (11.5.6.8) refers specifically to the *itihāsa-purāṇa* and 13.4.3.13 refers to the recitation of the Purāṇa. There is a similar reference in the Chandogya Upaniṣad 3.4.1.

According to the Viṣṇu Purāṇa, the original Purāṇa was transmitted to Romaharṣaṇa by Vyāsa. Romaharṣaṇa taught it to his six disciples, including his son Ugraśravas, when the Purāṇa consisted of 4,000 verses. The oldest three Purāṇas, the Vāyu, the Matsya, and the Brahmāṇḍa, are said to have been narrated in the reign of Adhisīmakṛṣṇa, the great-great grandson of Parīkṣit. The Vāyu Purāṇa was first narrated to a gathering of ṛṣis, performing their twelve year sacrifice in the Naimiṣa forest on the bank of the river Dṛṣadvatī.

A Purāṇa has five distinguishing marks: *sarga* (primary creation of the universe), *pratisarga* (secondary creation), *vaṃśa* (genealogy), *manvantarāṇi* (the reigns of Manus in different yugas), and *vaṃśānucarita* (history). Within this framework the bards found fit to add new episodes, but king lists always remained an important component of the books. Over the centuries the Purāṇas became enlarged with additional material and reworking of old material.

The Viśṇu Purāṇa gives genealogies of the various dynasties of which that of the Aikṣvākus is the most complete giving ninety three generations from the mythical Manu to Bṛhadbala of the Bhārata battle. The dynasty of the Pūrus is assigned fifty three generations for the same period. Clearly, the lists are not complete and in fact the Purāṇic tradition itself claims that the lists are incomplete[22] (e.g. Matsya P. 49.72). This is true even of the Ikṣvāku line, which is the longest (e.g. Vāyu P. 88.213). It appears therefore that some other system of reckoning was also used because we find it is possible to obtain a consistent list by the use of internal synchronisms and through cross-validation with independent sources.

The early Western reconstructions of the Indian ancient history were rightly criticized by F.E. Pargiter when he wrote in 1922: "The views about ancient India now held by scholars are based upon an examination of the Veda and Vedic literature, to the neglect of Purāṇic and epic tradition; that is, ancient Indian history has been fashioned out of compositions, which are purely religious and priestly, which notoriously do not deal with history, and which totally lack the historical sense. The extraordinary nature of such history may be perceived, if it were suggested that European history should be constructed merely out of theological literature. What would raise a smile if applied to Europe has been soberly accepted when applied to India."[23]

## Vedic and Purāṇic genealogies

Vedic genealogies of ṛṣis are found in the Śatapatha Brāhmaṇa (10.6.5.9) and Bṛhadāraṇyaka Upaniṣad (2.6; 4.6; 6.5) but such lists are not characteristic of the Vedic books. The Anukramaṇīs provide invaluable references to the composers of the hymns. Vedic books do not present history in any systematic fashion. Nevertheless, the isolated references to kings and ṛṣis may be compared usefully with the independent references in the Purāṇas to obtain a rough chronological framework for the events of the Vedic times.

Some famous kings of the epics and the Purāṇas were Māndhātṛ, Hariścandra, Sagara, Bhagīratha, Daśaratha and Rāma of Ayodhya; Śaśabindu and Arjun Kārtavīrya of the Yādavas; Duṣyanta, Bharata, Ajamīḍha, Kuru and Śantanu of the Pauravas; Jahnu and Gādhi of Kānyakubja; Divodāsa and Pratardana of Kāśī; Vasu Caidya of Cedi and Magadha; Marutta Āvīkṣita and Tṛṇabindu of the Vaiśāla kingdom; and Uśīnara and Śivi of the Ānavas. Of these that are mentioned in the Ṛgveda are Bharata (RV 6.14.4), Śantanu

(RV 10.98.1), Ajamīḍha (RV 4.44.6), Māndhātṛ (RV 1.112.13, 8.39.8, 8.40.12) and Rāma (RV 10.93.14). Furthermore RV 10.34 is attributed to Māndhātṛ and RV 10.179.1 is attributed to Śivi and 10.179.2 is attributed to Pratardana.

Of kings lauded in the Ṛgveda Vadhryaśva, Divodāsa, Sṛñjaya, Sudās, Sahadeva and Somaka appear as kings in the North Pañcāla genealogy but there is no description of their exploits. Other Ṛgvedic kings such as Abhyāvartin Cāyamāna, Śrutarvan Ārkṣa, Plāyogi Āsaṅga and Svanaya Bhāvya are unknown in the epics and the Purāṇas.

That Sudās, the most famous king of the Ṛgveda, should just be a name in the Purāṇas may be explained in two ways: first, this king lived long before the compilation of the genealogies; and second, that the focus of his exploits was far from the region where the Purāṇic genealogies were organized. The Purāṇas themselves claim that the *sūtas* were originally from the eastern regions of Magadha and Anūpa[24] far from the locale of the Sudās battle in north Punjab.

Purāṇic genealogies begin with the mythical Manu Vaivasvata. He had several offspring of whom his daughter Ilā bore a son named Purūravas Aila; their further successors represent the Aila or Lunar branch of the Vedic people. Manu's chief son Ikṣvāku became the king of Madhyadeśa with the capital at Ayodhyā. The Aikṣvākus are the Solar dynasty.

Amongst the Ailas, Purūravas was succeeded by Āyu, he in turn was succeeded by the famous king Nahuṣa whose son and successor was Yayāti. The kingdom expanded a great deal during his reign and Yayāti divided up this state amongst his sons Yadu, Turvasu, Druhyu, Anu and Pūru. The list of the kings is shown in the tables that follow.

## Reconstruction of genealogies

The Viṣṇu Purāṇa and other Purāṇas provide various king lists that were collated by Pargiter,[25] who used synchronisms to place the kings of the main Aikṣvāku list in relation to the kings in the even less complete lists of the other dynasties. He was also able to establish the general credibility of the lists by comparison with the well preserved information of the Vedic books.

Pargiter drew attention to the fact that the genealogies are more complete in regard to the eastern kingdom of Ayodhya. He argued that the focus of the civilization described in the Purāṇas was eastern India. He described the division into the yugas as follows:[26]

> The Kṛta age then ended with the destruction of the Haihayas [by Rāma Jāmadagnya]; the Tretā began approximately with Sagara and ended with Rāma Dāśarathi's destruction of the Rākṣasas; and the Dvāpara began with his reinstatement at Ayodhyā and ended with the Bhārata battle; so that, taking the numbers in the table of genealogies, the division is approximately thus, the Kṛta Nos. 1-40, the Tretā Nos. 41-65, and the Dvāpara Nos. 66-95.

The Vedic texts provide corroborating information on these kings. These texts also have genealogies of sages. Although some names occur at multiple places and times, one can by careful analysis distinguish between these different individuals. The synchronisms allow us to see the development of the Vedic literature as a historical process.

What was the Purāṇic theory of the yugas? According to Vāyu P. 32.58-64 Kṛta yuga is 4,000 years together with 400 years of sandhyās on either side; Tretā yuga is 3,000 years with total sandhyā periods of 600 years; Dvāpara is 2,000 years with sandhyās of 400 years; and Kaliyuga is 1,000 years with sandhyās of 200 years. In other words, the four yuga periods are 4,800, 3,600, 2,400 and 1,200 years, respectively. Taken together the cycle of the four yugas amounts to a total of 12,000 years, and the process repeats.

To summarize the lists, one sees that there are ninety five generations before the Bhārata War. The references to kings and ṛṣis are distributed over the entire range. Yayāti is at generation number six, Divodāsa of Kāśī at twenty five, Hariścandra of Ayodhyā at thirty three, Bharata of the Pauravas at forty four, Bhagīratha of Ayodhyā at forty five, Rāma of Ayodhyā at sixty five and Pratīpa of the Pauravas is at eighty seven. Pargiter uses the internal evidence to show that many kings and ṛṣis at different periods shared the same names and this is the source of much confusion. He placed the first Viśvāmitra at generation number thirty two and Vāmadeva, the author of the fourth book of the Ṛgveda at sixty ninth generation.

| **Royal Genealogies: Generations 1-33** | | | | |
|---|---|---|---|---|
| Gen | Yādavas | Pauravas | Ayodhyā | Other Kings etc |
| 1 | Manu | Manu | Manu | Cycle begins |
| 2 | Ilā | Ilā | Ikṣvāku | lunar/solar divide |
| 3 | Purūravas | Purūravas | Vikukṣi-Śaśāda | Fire altars |
| 4 | Āyu | Āyu | Kakutstha | |
| 5 | Nahuṣa | Nahuṣa | Anenas | |
| 6 | Yayāti | Yayāti | Pṛthu | |
| 7 | Yadu | Pūru | Viṣṭarāśva | |
| 8 | Kroṣṭu | Janamejaya I | Ārdra | |
| 9 | | Pracinvant | Yuvanāśva I | |
| 10 | | Pravīra | Śrāvasta | |
| 11 | Vṛjinīvant | Manasyu | Bṛhadaśva | |
| 12 | | Abhayada | Kuvalāśva | |
| 13 | | Sudhanvan | Dṛḍhāśva | |
| 14 | Svāhi | Bahugava | Pramoda | |
| 15 | | Saṃyāti | Haryaśva I | |
| 16 | | Ahaṃyāti | Nikumbha | |
| 17 | Ruśadgu | Raudrāśva | Saṃhatāśva | |
| 18 | | Ṛceyu | Akṛśāśva | |
| 19 | Citraratha | Matināra | Prasenajit | |
| 20 | Śaśabindu | Taṃsu | Yuvanāśva | |
| 21 | Pṛthuśravas | | Māndhātṛ | Aṅgāra (Druhyu) |
| 22 | Antara | | Purukutsa | |
| 23 | | | Trasadasyu | Jahnu (Kānya.) |
| 24 | Suyajña | | Sambhūta | |
| 25 | | | Anaraṇya | Divodāsa I (Kāśi) |
| 26 | Uśanas | | Trasadaśva | Aṣṭāratha (Kāśi) |
| 27 | | | Haryāśva II | Durdama (Haiha.) |
| 28 | Śineyu | | Vasumata | |
| 29 | | | Tridhanvan | Kekaya (Ānava) |
| 30 | Marutta | | Trayyāruṇa | Gādhi (Kānya.) |
| 31 | | | | Arjuna (Haihaya) |
| 32 | Kambalabarhis | | Satyavrata | Viśvāmitra (Kān.) |
| 33 | | | Hariścandra | |

**Royal Genealogies: Generations 34-65**

| Gen | Yādavas | Pauravas | Ayodhyā | Other Kings etc |
|---|---|---|---|---|
| 34 | Rukmakavaca | | Rohita | Tālajaṅgha (Haih.) |
| 35 | | | Harita, Cañcu | Pracetas (Druhyu) |
| 36 | Parāvṛt | | Vijaya | Vītihotra (Haihaya) |
| 37 | | | Ruruka | |
| 38 | Jyāmagha | | Vṛka | Sucetas (Druhyu) |
| 39 | | | Bāhu (Asita) | Sudeva (Kāśi) |
| 40 | Vidarbha | | | Divodāsa II (Kāśi) |
| 41 | Krathabhīma | | Sagara | Bali (Ānava) |
| 42 | Kunti | | Asamañjas | |
| 43 | Dhṛṣṭa | Duṣyanta | Aṃśumant | |
| 44 | Nirvṛti | Bharata | Dilīpa I | |
| 45 | Vidūratha | | Bhagīratha | Gaṅgā shifts |
| 46 | Daśārha | (Bharadvāja) | Śruta | |
| 47 | Vyoman | Vitatha | Nābhāga | |
| 48 | Jīmūta | Bhuvamanyu | Amabarīṣa | |
| 49 | Vikṛti | Bṛhatkṣatra | Sindhudvīpa | |
| 50 | Bhīmaratha | Suhotra | Ayutāyus | |
| 51 | Rathavara | Hastin | Ṛtuparṇa | |
| 52 | | | Sarvakāma | |
| 53 | Daśaratha | Ajamīḍha | Sudāsa | |
| 54 | Ekādaśaratha | | Mitrasaha | |
| 55 | Śakuni | Nīla | Aśmaka | |
| 56 | Karambha | Suśānti | Mūlaka | |
| 57 | | Purujānu | Śataratha | |
| 58 | Devarāta | Ṛkṣa | Aiḍaviḍa | |
| 59 | Devakṣatra | Bhṛmyaśva | Viśvasaha I | |
| 60 | Devana | Mudgala | Dilīpa II | |
| 61 | Madhu | Brahmiṣṭha | Dirghabāhu | |
| 62 | Puruvaśa | Vadhryaśva | Raghu | |
| 63 | Purudvant | Divodāsa | Aja | |
| 64 | Jantu | Mitrayu | Daśaratha | |
| 65 | Satvant | Maitreya | Rāma | Dvāpara begins |

| **Royal Genealogies: Generations 66-95** | | | | |
|---|---|---|---|---|
| Gen | Yādavas | Pauravas etc | Ayodhyā | Other Kings |
| 66 | Bhīma | Sṛñjaya | | Caturaṅga |
| 67 | Andhaka | Cyavana | Kuśa | |
| 68 | | Sudāsa | Atithi | |
| 69 | Kukura | Saṃvaraṇa | Niṣadha | |
| 70 | | Somaka | Nala | |
| 71 | | Kuru | Nabhas | |
| 72 | | | Puṇḍarīka | |
| 73 | Vṛṣṇi | Parīkṣit I | Kṣemadhanvan | |
| 74 | | Janamejaya II | Devānīka | |
| 75 | | Bhīmasena | Ahīnagu | |
| 76 | | Vidūratha | Pāripātra | |
| 77 | Kapotaroman | Sārvabhauma | Bala | |
| 78 | | Jayatsena | Uktha | |
| 79 | | Arādhin | Vajranābha | |
| 80 | Viloman | Mahābhauma | Śaṅkhan | |
| 81 | | Ayutāyus | Vyuṣitāśva | |
| 82 | | Akrodhana | Viśvasaha II | |
| 83 | Nala | Devātithi | Hiraṇyābha | |
| 84 | | Ṛkṣa II | Puṣya | |
| 85 | | Bhīmasena | Dhruvasandhi | |
| 86 | Abhijit | Dilīpa | Sudarśana | |
| 87 | | Pratīpa | Agnivarṇa | |
| 88 | | | Śīghra | |
| 89 | Punarvasu | | Maru | |
| 90 | | Śantanu | Prasuśruta | |
| 91 | | (Bhīṣma) | Susandhi | |
| 92 | Ugrasena | Vicitravīrya | Amarṣa | |
| 93 | Kaṃsa | Dhṛtarāṣṭra | Viśrutavant | |
| 94 | Kṛṣṇa | Pāṇḍavas | Bṛhadbala | Bhārata War |
| 95 | Sāmba | Abhimanyu | Bṛhatkṣaya | |

Pargiter places Sudās at number sixty eight whereas the Druhyus who left the country are placed at thirty eight. This indicates a possible error in his synchronism. Pargiter's lists cannot be considered to be the final word, but they are a useful starting point. In spite of the limitations of the lists, Pargiter is to be commended for the care that he took in obtaining his synchronisms. But his interpretation of the lists was vitiated by his own implicit use of the incorrect theories about the spread of Aryans within India.

In order to conform with the Max Müller date for the composition of the Ṛgveda, Pargiter considered that the Bhārata battle took place around 950 BCE. Assuming that each king ruled approximately for twelve years he traced the genealogies to about 2000 BCE. He concluded that the Aryans of Ayodhya were the first to enter India and there were later invasions from the northwest. He also concluded that "Brahmanism originally was not an Aryan institution. The earliest brahmans were connected with the non-Aryan peoples."[27] This inference is contradicted by a host of evidence within the Vedic literature.

Since Pargiter's work was done before the discovery of the Sindhu-Sarasvatī civilization he was not able to use archaeological checks for his assumptions. He did not use the internal tradition in the Purāṇas regarding the time span between the king Parīkṣit and the Nandas and he did not use the fact that the lists are incomplete. But he demonstrated that with the most conservative view of the data there was no escaping the fact that the Indian tradition went back to at least 2000 BCE.

A later attempt by Bhargava[28] departs from Pargiter in assigning a more realistic period of twenty years per generation. Considering one hundred generations of kings upto the time of the Bhārata battle this took him to 3000 BCE as the dawn of Indian history. But his work remains limited because of two assumptions: (i) that the Bhārata battle took place in about 1000 BCE; he also used unconvincing arguments to reconcile it with Purāṇic statements; (ii) seeing the Aryans only in the Sapta Saindhava area during the Ṛgveda era which is in contradiction to the internal evidence of the Purāṇas. The provenance of the kings and the ṛṣis shows that the Aryans were spread to about the current geographical extent of the Indo-Aryan languages in India during the Ṛgvedic times itself.

The Ṛgveda (RV 8.9.2) speaks of five peoples (*pañca mānuṣān*); in RV 1.108.8 they are named as Yadu, Turvasu, Druhyu, Anu, and Pūru which have been identified as five Aryan *tribes* that are described in the Purāṇas as the sons of Yayāti. According to the

Purāṇas, the Pūrus were located in the Punjab region and a disproportionately large number of kings mentioned in the Ṛgveda belong to the Pūrus.

The evidence from the Purāṇas clearly indicates at least one hundred kings in a genealogical succession before the Bhārata battle. If an average span of twenty years is assigned to each king this provides a period of 2,000 years for the duration of the Vedic age which takes us back to the Harappan period even if the most conservative chronology is used. It raises important questions of placing the Bhārata battle within the framework provided by the recent archaeological discoveries from India.

## The Bhārata War

Let us review the three main Indian traditions regarding the time of the Bhārata War. The fact that there exist multiple traditions for this means that several attempts were made in India to arrive at a consistent chronology.

*1. The Purāṇic Evidence*

To examine this tradition we depend on the collation of the relevant data by Pargiter. According to the Purāṇas (such as Vāyu 99.415; Matsya 73.36 etc) a total of 1,050 years (in certain texts 1,015, 1115, or even 1,500 years) elapsed between the birth of King Parīkṣit and the accession of Mahāpadma Nanda. Moreover the interval from Mahāpadma to the last Andhra king Pulomāvi was 836 years.

Based on his collation, Pargiter suggested an important emendation as follows:[29]

> The Great Bear (the ṛkṣas or the Seven Sages or Saptarṣi) was situated equally with regard to *the lunar constellation* Puṣya while Pratīpa was king. At the end of the Andhras, who will be in the 27th century *afterwards*, the cycle repeats itself. In the circle of the lunar constellations, wherein the Great Bear revolves, and which contains 27 *constellations* in its circumference, the Great Bear remains 100 years in (*i.e.* conjoined with) each in turn.

This implies a period of 2,700 years from a few generations before the War to the middle of the third century CE. Support for this reading comes from the following statement that is often misinterpreted: The Saptarṣi were in Maghā at the time of Yudhiṣṭhira but they had shifted to Pūrvāṣāḍhā (ten nakṣatra on) at the time of Nanda and Śatabhiṣaj (a further four nakṣatras) at the end of the reign of the Andhras (Vāyu P. 99.423).

This astronomical evidence would point to a gap of about 1,000 years between Parīkṣit and Nanda and another 400 years between Nanda and the end of the Andhras. Considering that Pratīpa was only seven generations before Parīkṣit, or about 150 years earlier, this gives a total interval which is about one-half the interval of 2,700 years mentioned just above. But we do know that the gap between Nanda and the end of the Andhras was more than 800 years. It is clear that this second reference counts two hundred years for each nakṣatra. This may have had something to do with the Jain tradition[30] that counted the 54 nakṣatras twice.

As for the duration of reigns, Vāyu P. 99.416 speaks of a gap of 829 years between Nanda and the end of Andhras. Elsewhere this gap is given to be 836 years. Adding the dynastic lists with 100 years to the Nandas, 137 years to the Mauryas, 112 years to the Śungas, 45 years to the Kaṇvas, and 460 years to the Andhras one gets a total of 854 years.

The Purāṇas also assign one hundred years to Mahāpadma Nanda and his eight sons. Furthermore, in Magadha are assigned 22 Bārhadrathas, 5 Pradyotas and 10 Śiśunāgas for the period between the Bhārata War and the inauguration of Mahāpadma Nanda for a total of (967+138 +346) or 1,451 years. Sengupta (1938) argues that to the Pradyotas one should add another 52 years giving a total of 1,503 years. Over the same period are said to have ruled 30 Paurava kings and 29 Aikṣvākus. It is also stated that when Mahāpadma Nanda defeated the kṣatriyas, there had reigned since the Bhārata War 24 Aikṣvākus, 27 Pañcālas, 24 Kāśis, 28 Haihayas, 32 Kaliṅgas, and so on.

Considering that Candragupta became king about 320 BCE, the direct reference to the years elapsed leads to the date of 1924 BCE. But clearly the average reigns for the kings are too long unless these lists are incomplete and the names are the most prominent ones in which case there would have been other kings who ruled for very short intervals. If this were so then the actual year of the Bhārata War would be prior to 1924 BCE.

If the nakṣatra reckoning was for some reason done per each two centuries, as the gap of 829 years for four nakṣatras indicates, then there should be about 2,000 years between Parīkṣit and Nanda.

This would take the Bhārata battle to around the middle of the third millennium BCE, and we will show later that a case can be made for 2449 BCE.

Considering that the lists are complete and that the year assignments are wrong, various suggestions have been made for the duration of the average reign. Using the statement that ten centennials (ten nakṣatras) had passed between the time of Parīkṣit and Nanda, one gets approximately 1,100 years upto Candragupta which yields circa 1420 BCE for the War. Since A. Cunningham in the nineteenth century proposed 1424 BCE for the War, this specific year has been often defended by several scholars including Roy.[31]

In addition to these we also have 950 BCE obtained by Pargiter using the genealogies of the Purāṇas and this will be examined shortly.

*2. The Kaliyuga Tradition*

According to the famous astronomer Āryabhaṭa (c. 500 CE) the Kaliyuga began in 3102 BCE which the Mahābhārata says happened thirty five years after the conclusion of the battle. This implies the date of 3137 BCE for the War.

*3. Varāhamihira's Statement*

Varāhamihira (550 CE) claims that according to the earlier tradition of the astronomer Vṛddha Garga the Pāṇḍava king Yudhiṣṭhira was ruling 2,526 years before the commencement of the Śaka era (Bṛhatsaṃhitā 13.3). This amounts to 2449 BCE for the War and 2414 BCE for the beginning of the Kali era.

There is no reference to the Kaliyuga in texts before Āryabhaṭa and so it is claimed that this era was devised by Āryabhaṭa or his contemporaries. The first inscriptional reference to this era is in the Aihole inscription of 633/634 C.E.

After analyzing the astronomical evidence, P.C. Sengupta spoke in favour of the date of 2449 BCE. Cunningham's date of 1424 BCE has the virtue of being conservative and Pargiter's date has been popular because it is the most conservative. We will examine these conflicting accounts and see if they can be compared considering independent evidence. Here we use the king lists of the epics and the Purāṇas, the Greek evidence and contemporary archaeological insights.

## Analysis of the Literary Evidence

### The Purāṇic Evidence

We saw that the Purāṇic data is interpreted variously to give dates for the Bhārata War that range from the low of 950 BCE to the high of mid-third millennium BCE. Each one will be separately examined.

### 950 BCE

Pargiter justified this date on the basis that the reign periods were all incorrect and perhaps fictional. He further implicitly assumed that the king lists was complete. Considering the interval between Parīkṣit and Mahāpadma Nanda, he reduced the number of kings in the longest line of the Pauravas from 36 to 26 and calculated the average of number of kings in ten kingdoms. This average turned out to be 26 and he assigned an interval of 18 years to each reign thus obtaining a total period of 468 years. During the same period there had been 31 Magadha kings and this meant assigning an average of 14.5 years to each king in that line. Next he reduced the period of the Nandas to 80 years, by considering that Mahāpadma Nanda ruled till he reached the age of 80 years and he must have been, say, twenty when he became king, and his successors ruled for twenty years. Considering that Candragupta Maurya began his reign in 322 BCE this gave (322+ 60+ 468) or 850 BCE for Parīkṣit. Assuming 100 years for the five Pauravas, including the reign of Yudhiṣṭhira, from the Bhārata War to Parīkṣit, he obtained the epoch of 950 BCE for the War.

The date of 950 BCE contradicts the internal evidence of the Purāṇas; it also contradicts the totals of the reigns. It considers the averages in a fashion obtained clearly by a back-calculation to conform to the date of 950 BCE. In other words, it cannot be considered to be independent of the arbitrary dating of 1,000 BCE for the Ṛgveda by Max Müller. The most significant objection against this date is that it cannot point to the archaeological processes accompanying the rise of the kingdoms prior to this date.

If one were to consider the longest list of 36 kings out of the several dynasties as outlined above and assign twenty years to each reign, which is not an unreasonable assumption, and restore the hundred years to the Nandas, then we get 1222 BCE for the War.

What is fatal for this date is the evidence related to the list of teachers from Bṛhadāraṇyaka Upaniṣad. Three lists are given: at the end of the second, the fourth, and the sixth chapters (adhyāyas). The list at the end of the sixth chapter gives the names as sons of such and such mother and so it cannot be compared to the other two more traditionally represented lists. These two lists are identical somewhat before the time of Yāska, who is twenty fifth in one list and twenty seventh in the other. This Yāska is paired with Āsurāyaṇa and we see the same pairing in the Purāṇa lists where Yāska come eight generations after Parīkṣit. Considering Pargiter's 850 BCE for Parīkṣit and counting a conservative 160 years for these eight generations brings us down to 690 BCE. But Yāska is at least twenty five generations removed from the time of the writing of the Bṛhadāraṇyaka text which would require a minimum of another 500 years bringing down the date of the Upaniṣad to 190 BCE. Now it is clear from other evidence that this Upaniṣad, which constitutes the concluding portion of the Śatapatha Brāhmaṇa, is pre-Buddhistic and there is no way it can be considered to be later than 600 BCE. In other words, the latest one can date the Bhārata War based on the teacher chronologies is about 1350 BCE.

In summary, the 950 BCE date for the War is in such contradiction with the Vedic evidence that it should be considered too late by at least several centuries.

**1424 BCE**

This date is suggested by the mention in the Purāṇas of the interval of 1,050 years between Parīkṣit and Nanda. This date is too late by 447 years when compared to the totals of the reigns in the Purāṇas. But it does bring the average reign period to the realm of possibility as it reduces to about 27 years, assuming of course that the lists are complete. The fact that a submerged temple at Dvārakā dating to the middle of the second millennium BCE is taken as the evidence of the destruction of that city soon after the Bhārata War. However, we do not know if this temple is from the era of the loss to the sea soon after the Bhārata War.

There is no archaeological evidence suggesting a flowering of culture around 1500 BCE. For this epoch for the War, one would expect evidence for the tremendous literary activity related to the arrangement of the Vedas and the composition of the other texts.

We must reject this date if we consider the evidence related to the Sarasvatī river, which was the major river during the time of the Bhārata War. Since this river dried up around 1900 BCE, the figure of 1424 BCE for the War is too late. The rapid decline around 1900 BCE of cities, such as Kalibangan, in the mid-course of the Sarasvatī, makes it impossible for us to assume that the river could have somehow been called "major" when it ceased to flow all the way to the ocean.

### 1924 BCE

This date is a result of the stated interval of 1,500 years between Parīkṣit and Nanda, and the count obtained by adding up the durations of the reigns. This appears to be the original interval of the Purāṇas that became corrupted. Pargiter suggested that the Purāṇas, as living bardic material, were transcribed into Sanskrit sometime between the reigns of the Śungas and the Guptas from Prakrit. This translation often used ambiguous constructions which is how the figure of 1,500 was read wrongly at some places. According to Lalit Mohan Kar,[32] "If a comparative estimate is desired between the totals, as given by the different Purāṇas (vis., 1015, 1050 and 1115 years), and the sum total found by calculation of the details [1500 years], the scale must turn in favor of the latter, as a corruption, or at least a variation, depends on the mutation of two or three letters of the alphabet, as is evident from there being those different versions of the total period, while the details are more definite."

If the Bhārata War story was a metaphor for the natural catastrophe that occurred in India around 1900 BCE, then this is the correct date. Conversely, if the War did take place (although it was remembered in an embellished form), then the natural catastrophe may have contributed to it by causing a breakdown of the old order.

### 2449 BCE

This is the date mentioned by Varāhamihira. The Purāṇas may be interpreted to point to this date, and also this date may be correct if the genealogies represent only the chief kings.

It is indirectly supported by the archaeological evidence. Since a great deal of literary output of Vedic times was produced and arranged during the centuries after the War, one would expect that such efforts would have been supported by kings and that one would find a correlation with prosperity in the land. The archaeological evidence indicates that the Harappan era represents a period of great prosperity.

If this date is true, then the Harappan phase of the Sindhu-Sarasvatī tradition is essentially post-Vedic. But this date also implies that the genealogical lists are hopelessly incomplete which is plausible if a great catastrophe, such as the drying up of the Sarasvatī, caused the tradition to be interrupted.

### 3137 BCE

The problem with this date is that the Purāṇic evidence does not support it. Some scholars have suggested that the Sarasvatī river went through two phases of diminution: *first*, around 3000 BCE, after which the river ceased to flow all the way to the sea; *second*, 1900 BCE, when due to further shrinkage the river was unable to support the water needs of the communities around it, ending the most prosperous phase of the Harappan era. Since the Ṛgveda describes the Sarasvatī as sea-going so, going by this theory, the Ṛgveda must be prior to 3000 BCE.

This date could be reconciled with the Purāṇic accounts only if we take it to define the last phase of the Ṛgveda and assume that the Bhārata War was wrongly transferred to this earlier era when the last major assessment of ancient Indian eras and history was done during the early Siddhāntic period of Indian astronomy in early centuries CE.

## The Saptarṣi Era and the Greek Notices

The tradition of the seven ṛṣis, the stars of the Ursa Major, in India is an ancient one and it goes back to the Ṛgveda. The Śatapatha Brāhmaṇa speaks of a marriage between the ṛṣis and the nakṣatras, and it is mentioned that the ṛṣis were married to the Kṛttikās. In the Purāṇas this notion of marriage is elaborated when it is stated that the ṛṣis remain for a hundred years in each nakṣatra. This Purāṇic account implies a centennial reckoning system with a cycle of 2,700 years. Such a system has been in use in parts of India for a long time that goes back centuries before CE and it is called the Saptarṣi era. Each cycle of 2,700 years is called a *cakra*, or cycle. By current reckoning in Kashmir, which goes back at least to Kalhaṇa (1150 C.E.), Saptarṣi era began in 3076 BCE. Cunningham[33] provided a careful analysis of the traditions related to this era.

Mitchiner[34] suggested that the Saptarṣi era goes back to 6676 BCE. He argued that it is the beginning of this era that is quoted by the Greek historians Pliny and Arrian:

> From Father Liber to Alexander the Great, they reckon the number of their kings to have been 154, and they reckon (the time as) 6,451 years and 3 months. [Pliny, *Naturalis Historia*, 6.59-60]
>
> From Dionysos to Sandrocottos (Candragupta) the Indians count 153 kings, and more than 6,042 years; and during this time, thrice for liberty ... this for 300 years, the other for 120 years. [Arrian, *Indica*, 9.9]

These two traditions, perhaps derived from the same source, may be reconciled if the Arrian years are all added up, which gives (6,042+ 300+ 120) or 6,462 years, which is only 11 years different from the other account. These eleven years might represent the gap between the time of Alexander and the Greek embassy to Candragupta Maurya. If one takes the year 314 BCE for the embassy to Candragupta, one gets 6776 BCE as the beginning of the Indian calendar in use at that time. This is just one centennial removed from the epoch of 6676 BCE suggested by its current beginning of 3076 BCE together with an additional 3,600 years.

As to the count of 153 or 154 kings, it accords quite closely if one follows up the list until the Bhārata War with the kings of the Magadhan line together with the ten kings of the Bārhadrathas, whose names the Purāṇas tell us are lost. This total upto Candragupta is 143 which is only ten or eleven less than the Greek total. This near accord tells us that we had substantially the same king lists in the fourth century BCE as we have now excepting that the current lists have dropped a few names. This loss of about ten kings from the lists in a span of five or six hundred years when the current versions of some of the Purāṇas became fixed suggests that a similar loss might have occurred before and it supports the view that the genealogies are incomplete.

Cunningham[35] argued that the Kaliyuga and the Varāhamihira traditions about the Bhārata War can be reconciled if it is assumed that a change in reckoning from a system of 28 nakṣatras to that of 27 nakṣatras took place sometime after the time of Candragupta. He and Mitchiner suggest that the original list of 28 naksṭras which is given in the Atharvaveda was amended in the medieval times to 27. It was also suggested that the Kaliyuga tradition might be authentic and the Varāhamihira one was derived from it.

But the evidence from the Ṛgveda supports the notion that the original system of nakṣatras was 27 and that it was modified to 28 later. The nakṣatra year is mentioned in the Ṛgveda. The notion of 27 nakṣatras goes back very far in the Taittirīya Samhita as well.

The remembered tradition was that the War occurred when the Saptarṣi were in Maghā. When the list of nakṣatras was increased from 27 to 28 somewhat before Āryabhaṭa, it became necessary to assume that the beginning of the calendar in 6676 BCE was with a different nakṣatra. It is stated at many places that whereas Kṛttikā is the first nakṣatra for sacrifices, time calculations begin with Śravaṇā (e.g. Mahābhārata 14.44.2, although many manuscripts give Śraviṣṭhā).

In a centennial reckoning table starting with Śravaṇā in 6676 BCE, one reaches Maghā in 2476 BCE after completing one full cycle of 2,700 years as Maghā occurs fifteen places after Śravaṇā. One might assume that Āryabhaṭa tried to make the Saptarṣi count begin with Kṛttikā after adding one more nakṣatra and one can easily see that the requirement of Maghā defining the beginning of the Kaliyuga compels the earlier date of 3137 BCE.

Why do we not assume with Cunningham and Mitchiner that Kaliyuga was the original tradition and that it was later modified by Vṛddha Garga and picked up by the Purāṇas and Varahamihira? This is because we have no archaeological support for this early date and also because the Vedic texts clearly speak of 27 nakṣatras in the earliest layer. Further support for our view comes from the internal astronomical evidence of the Mahābhārata as analyzed by Sengupta.[36]It is also more plausible to see the flowering of the literature of the Vedic age to have occurred during the Harappan phase.

It is conceivable that the original text of Mahābhārata was remembered from the third millennium BCE and expanded much later in the first millennium BCE when the events and the geography got a contemporaneous coloring, but the main astronomical associations were not altered.

It is reasonable to assume that the Saptarṣi era was known during the Śatapatha Brāhmaṇa times. Note that the altar is made in an area 7 1/2 times that of one puruṣa. With 360 years considered one divine year, 2,700 years equal 7 1/2 divine years. It may be that such a theory led to the popularity of the system of 27 nakṣtras. It is also significant that the epoch of 6676 BCE is exactly 3,600 years before the starting point of 3076 BCE for the Saptarṣi era as accepted now. Since it is clear that at the time of the Mauryas the cycles of the Saptarṣi era were counted back to 6676 BCE, it appears that the new count that goes back to 3076

BCE was started later to make it as close to the start of the Kali era as possible.

Cunningham[37] provides another plausible explanation for the starting point of 6776 BCE for the tradition. He argues that by the time of the Greeks the nakṣatras were listed starting with Aśvinī (as in Sūrya Siddhānta 8.9). As Maghā is the tenth nakṣatra in a count beginning with Aśvinī, one needs to add 900 years (Cunningham says 1,000 but that is clearly wrong) to find the epoch for the beginning of the cycle. This takes one to 3976 BCE. One more complete Saptarṣi cycle of 2,700 years before that brings us to 6676 BCE.

Although the limitations and ambiguities of the Purāṇic evidence are obvious, archaeological discoveries indicating continuity in Indian culture going back to the seventh millennium BCE cannot be ignored. The calendrical framework described in the Purāṇas is perfectly consistent with the archaeological evidence.

## Vedic Teachers

Although the internal evidence of the texts and the archaeological evidence favors the epoch of 2449 BCE for the Bhārata War, one might wish to speak of a High Chronology and a Low Chronology to indicate the limits within which one might safely place the War. The date of 1424 BCE might be considered as the absolute minimum that one can assign to it and that of 3137 BCE as the earliest.

The Purāṇas give an account of the various Vedic teachers who came after Kṛṣṇa Dvaipāyana Vyāsa had arranged the Vedas. These teachers established schools with their own recensions. Vyāsa had four disciples and he entrusted the Ṛgveda to Paila, the Yajurveda to Vaiśampāyana, the Sāmaveda to Jaimini and the Atharvaveda to Sumantu. Vāyu Purāṇa (Chapters 60-61) and other Purāṇas provide the following account.

### Ṛgveda

Paila made two versions and gave these to his disciples Indrapramati and Bāṣkala. Bāṣkala made four Saṃhitās of his version and taught them to his four disciples Bodhya, Agnimāṭhara, Parāśara and Yājñavalkya. Indrapramati's Saṃhitā passed to Mārkaṇdeya who taught it to his eldest son Satyaśravas; he in turn taught it to his disciple Satyahita; he to his son Satyarata; he to Satyaśrī.

Satyaśrī had three disciples named Śākalya, Rathītara Śākapūrṇa and Bāṣkalī Bharadvāja; each of these established a separate śākhā.

Śākalya lost a debate with Yājñavalkya, son of Brahmavāha, at the court of King Janaka of Videha and as a condition of this debate he had to forfeit his life. Śākapūrṇa Rathītara made three Saṃhitās and also a nirukta. He had four disciples: Ketava, Dālakī, Śatabalāka and Naigama. Bāṣkali Bharadvāja made three Saṃhitās and he had three disciples Nandāyanīya, Pannagāri and Aryava.

### Yajurveda

Vaiśampāyana made eighty six Saṃhitās and all his disciples, excepting Yājñavalkya, son of Brahmarāta or Devarāta according to different accounts, received one each. These disciples were considered in three geographical groups: the northern, the middle and the eastern, the chiefs of which were respectively Śyāmāyani, Āruṇi (or Āsuri) and Ālambi. They were called Carakas, Caraka Adhvaryus, or Taittirīyas.

Yājñavalkya Brahmarāti made his own Saṃhitā. He taught his version to his fifteen disciples: Kaṇva, Vaidheyaśālī, Madhyandina, Śāpeyī, Vidigdha, Āpya, Uddala, Tāmrāyaṇa, Vātsya, Gālava, Śaiṣiri, Āṭavī, Parṇī, Vīraṇī and Saparāyaṇa. Each of these made a different version; they were called Vājins. Altogether, there were one hundred and one recensions.

### Sāmaveda

Jaimini's grandson Sukarman made a thousand Saṃhitās of it. Sukarman had two famous disciples: Pauṣpiñji and Hiraṇyanābha Kausalya. Pauṣpiñji's disciples are called 'northern sāman chanters' whereas Hiraṇyanābha's pupils are called 'eastern sāman chanters'. Pauṣpiñji had Laugākṣi, Kuthumi, Kuśītin and Lāṅgali as his disciples. Laugākṣi had five disciples that led to schools such as Rāṇāyanīya and Taṇḍiputra. Kuthumi's three sons, the Kauthumas, formed their own schools. Lāṅgali's disciples included Jaimini (the younger) and they also formed own schools.

### Atharvaveda

Here the succession goes from Sumantu to Kabandha and then to the schools of Pathya and Devadarśa. The Pathyas had three divisions, those of Jājali, Kumudādi and Śaunaka; whereas Devadarśa taught four versions to Moda, Brahmabala, Pippalāda and Śaulkāyani. Śaunaka made two Saṃhitās and gave one to Babhru and the other to Saindhavāyana. Saindhava gave that to Muñjakeśa and it was again made into two.

The successions of the Vedic teachers provide a developmental background to the Saṃhitās. They also establish that the period of a few centuries after the Bhārata War was one of intellectual ferment and vigor.

# *4. Astronomy of the Fire Altars*

## Altars in the Literature

A fire altar, generally made of bricks, is called an agni, and the sacrificial area where the sacrifice is to be performed and where the sacrificer, the hotṛ, the adhvaryu and others take seat, and which includes the agni, is the vedi. Each layer of agni is called a citi.

The agni represents time and in sacrifices it represents the year. The agnicayana, or the building of a fire altar, is the symbolic creation of Agni-Prajāpati-Puruṣa.

The Mahābhārata speaks of how the fire altar ritual arose at a late stage in the history of the Vedic people. We will show that the altar ritual embodies the most subtle notions of the Vedic system of knowledge, which must have been in place when the altar ritual emerged.

There are several references to fire altars in the Ṛgveda. RV 1.164.35; 1.170.4; 5.31.12; 7.35.7; 8.19.18 and 10.61.2 are some of the places where the vedi is mentioned. Three places of Agni, which are doubtless gārhapatya, āhavanīya and dakṣiṇāgni, are mentioned in RV 5.11.2; gārhapatya finds specific mention in RV 1.15.12; 6.15.19; 10.85.27.

ŚB (7.1.1.37, 7.2.2.1) speaks of the gārhapatya being circular and of one square vyāma (=puruṣa) and that āhavanīya is a square of the same size. TS 5.2.5.1 speaks of the āhavanīya being of one square puruṣa.

The Taittirīya Saṃhitā (5.2.3) speaks of the gārhapatya being made of 21 bricks. It is also stated that if made for the first time it should be in five layers; for the second time in three layers; and for the third time it should be in one layer. The prescribed variation emphasizes the symbolic nature of the ritual.

After drawing the east-west line on the sacrificial ground, the prācīnavaṃśa (the sacrificial hall or shed) is erected at the western end. The vaṃśas are the horizontal beams supported by the four corner-posts. Inside this hall are set up the gārhapatya fire at the western end, the āhavanīya fire at the eastern end, and the dakṣiṇāgni fire is in the south near the western corner.

The gārhapatya is the householder's fire received from his father and passed on to his descendants. The āhavanīya is a consecrated fire taken from the householder's fire and used for cooking the offerings of the sacrifice. The dakṣiṇāgni is the fire where the priest's fee, dakṣiṇā, is cooked. The utkara is a pit for rubbish in the northeastern corner of this hall.

To the east of this hall lies the mahāvedi. The size of the saumikī or the mahāvedi is described in TS 5.2.3. It has the form of an isosceles trapezium whose face is 24 prakramas, base is 30 and altitude 36 prakramas. In the BSS 1.13, it is mentioned that the "areas (of the squares) produced separately by the length and the breadth of a rectangle together equal the area (of the square) produced by the diagonal. This is observed in rectangles having sides 3 and 4, 12 and 5, 15 and 8, 7 and 24, 12 and 35, and 15 and 36." The significance of the (15,36,39) triple derives from the fact that the sum of the three numbers is 90 (one-fourth the days in the year) which equals the size of the mahāvedi altar (base = 30, height =36, and top =24).

In the western side of the mahāvedi is the sadas tent. Inside this tent are six dhiṣṇya hearths. Of these six hearths five are placed on the northern side and and they belong to the 1) hotṛ, 2) brāhmaṇācchaṃsi, 3) potṛ, 4) neṣṭṛ, and 5) acchāvāka. The sixth hearth belongs to the maitrāvaruṇa or praśāstṛ priest and it is placed on the southern side of the tent. Two other dhiṣṇya hearths, the āgnīdhra and the mārjālīya, are placed in the middle part of the northern and the southern side of the mahāvedi.

To the east of the sadas shed is the havirdhāna shed which is used for the cart that has the soma plants for the rite. Uparavas are the four sounding holes dug out in the ground near the havirdhāna. The soma plants are ground over these holes.

The uttara vedi is raised near the eastern side of the mahāvedi. It is raised on the earth dug out from a pit, called cātvāla, near the northeast corner of the mahāvedi. The Taittirīya Saṃhitā 5.4.11 gives a list of various shapes in which the kāmya altar that is set up in the uttara vedi can be made. These are: chandas (symbolic altar of meters or chandas), śyena, kaṅka, alaja (different kinds of falcons), praüga (isosceles triangle), ubhayata praüga (rhombus), rathacakra (chariot wheel), droṇa (trough), paricāyya (circle) and śmaśāna (pyre: isosceles trapezium).

Construction of these altars is for the fulfillment of different objectives that are etymological or symbolic associations with the shapes chosen. Thus chandaścit is to gain cattle or livelihood by the priests because this altar could only be made by them who knew the mantras. The falcon represented the bird (and time) who could symbolically take the sacrificer's message to the gods; these altars were thus meant to gain heaven, prosperity or prestige. The triangle, the rhombus and the chariot wheel altars were for the annihilation of rivals; the inclusion of the chariot wheel is clear here, and praüga represented ownership. Likewise the association of droṇa with food, paricāyya with a region and śmaśāna (pyre) with the departed forefathers is clear. Figures 4.1, 4.2 and 4.3 show the development and some of the details of śyenacit. Figure 4.4 shows the rathacakra and the kūrma altars.

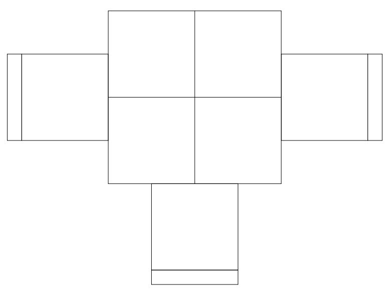


Figure 4.1: The basic bird altar

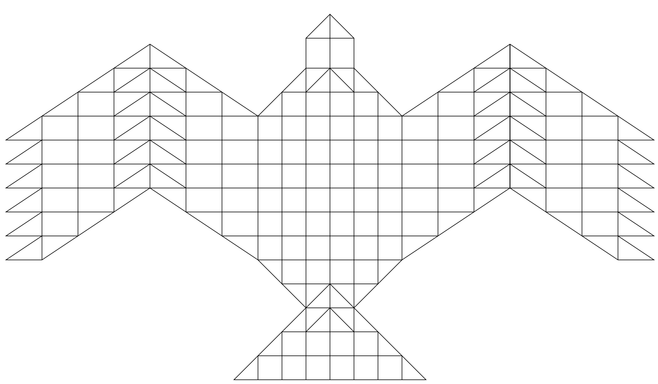


Figure 4.2: The bird altar in the shape of an eagle (śyenacit)

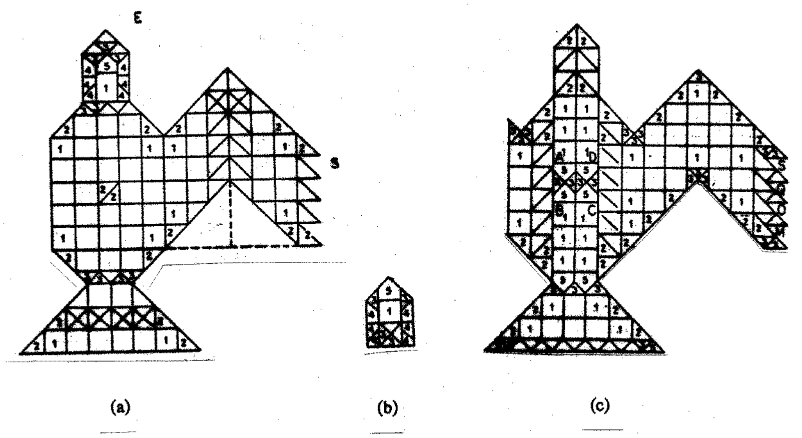



Figure 4.3: (a) Arrangement of bricks in the śyenacit in the first layer; (b) Another arrangement of bricks in the head; (c) Arrangement of bricks in the second layer. (North wing has not been shown.)

Apart from the great altars, smaller (kṣudra) altars are mentioned in the texts. These altars could be made of pieces of gold or pebbles or even water. The Taittirīya Brāhmaṇa mentions sāvitṛ, nāciketa, cāturhotra and vaiśvasṛja altars. Other altars include samuhya (combined), kūrma (tortoise) and so on.

Underlying the surface associations that connect altars to the ritual is the deeper representation of knowledge.[1] This was not only in terms of intricate geometric constructions that were a part of the ritual of the altars, but also in the oft-repeated claim that only self-knowledge sets one free. Yājñavalkya claims in ŚB 10.4.3.9, *eṣā haiva sā vidyā yadagniḥ etadu haiva tat karma yadagniḥ*, or the fire altar represents both knowledge and ritual.

## Of Bricks, Enclosing Stones, Hymns and Meters

In agnicayana, which is one of the Soma sacrifices, the altar is generally made in the shape of the falcon, *śyena* or *suparṇa*. This construction is in five layers that parallel the five layers of the physical and psychological universes.

Altars are made of bricks unless they are constructed symbolically of mantras. Bricks to be used in altar construction are clas-

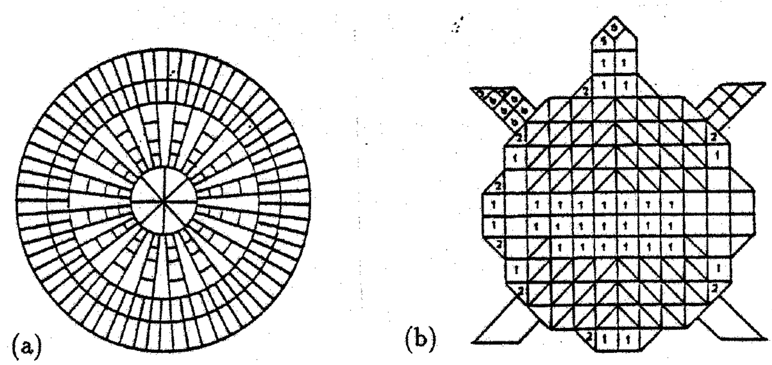



Figure 4.4: (a) Arrangement of bricks in the rathacakraciti; (b) Arrangement in the kūrmacit

sified into two types: ordinary, lokampṛṇā, and special, yajuṣmatī. Each yajuṣmatī brick is consecrated in a specific manner and each such brick is marked in a unique way. Bricks are built in different shapes to different measurements.

ŚB 10.4.3.14-20 describes the total number of yajuṣmatī bricks to be 396. This was to be taken as 360 days of the year and 36 additional (including one being the fillings between the bricks) as the days of the intercalary month. By layers, the first has 98, the second has 41, the third has 71, the fourth has 47, and the fifth has 138 (ŚB 10.4.3.14-18).

The sum of the bricks in the fourth and the fifth layers equals the 186 (together with the one space filling) tithis in the half-year. The number of bricks in the third and the fourth layers equals the integer nearest to one third the number of days in the lunar year. The number of bricks in the third layer equals the integer nearest to one fifth of the number of days in the lunar year. The number of bricks in the second and the third layers equals one third the number of days in a nakṣatra year of $28 \times 12 = 336$ days. Once the basic number of 21 is subtracted from the number of bricks in the first layer, the sum of the remainder together with the bricks in the second layer is once again the integer nearest one third the number of days in the lunar year.

The total lumber of lokampṛṇā bricks is 10,800 which equals the number of muhūrtas in a year (1 day = 30 muhūrtas), or equivalently the number of days in 30 years. Of these 21 go into the gārhapatya, 78 into the eight dhiṣṇya hearths, and the rest go into the āhavanīya altar.

The fire altars are surrounded by 360 enclosing stones (pariśrita), and of these 21 are around the gārhapatya, 78 around the dhiṣṇya, and 261 around the āhavanīya (ŚB 10.4.3.13). The āhavanīya includes the dhiṣṇya, therefore the number of days assigned exclusively to the āhavanīya is 261-78= 183 days, which is equal to the days in the uttarāyaṇa of a 366 day year.

The choice of the 21 days for the gārhapatya is from the symbolism of this number, which is the sum of the first six integers. Once the numbers 21 and 183 are chosen the number 78 becomes the only choice for the dhiṣṇya. This number 78 is the sum of the first twelve integers. It is of course possible that the choice of 21 is secondary and the primary number is 78.

The dhiṣṇya hearths are in one layer in a size of 18 aṅgulas in either a square or circular form. The number of enclosing stones equals the number of bricks used in a dhiṣṇya hearth, and these are 8 each for five of them with the remaining three using 6, 11, and 21.

## The Meters

ŚB 10.3.1 describes how the altar can also be constructed symbolically by the meters. The altar is made with gāyatrī (24 syllables) as the breath, uṣṇiḥ (28 syllables) as the eye, anuṣṭubh (32 syllables) as the voice, bṛhatī (36 syllables) as the mind, paṅkti (40 syllables) as the ear, triṣṭubh (44 syllables) as the generative breath, and the jagatī (48 syllables) as the downward breathing.

The Kāṭhaka Saṃhitā Brāhmaṇa speaks of the gāyatrī altar being upto the level of the knees, the triṣṭubh one upto the level of the navel and the jagatī upto the level of man's height. Clearly there were correspondences acknowledged between the altars of meters and that of bricks.

We will see later there is a correspondence with the size of the physical altar being seven (and a half) square units. Elsewhere the identification of the meters with the parts of the altar is different. The important correspondence is that of the meters being represented as a group of seven and this may be related to the fact that the octave consists of seven notes.

Note that Chāndogya U 2.10.5 speaks of 21 in connection with the sun, and uses that to explain why the octave has 22 śrutis:

> With twenty-one intervals (syllables) a man reaches

> the sun, for the sun is the twenty-first from here. With the twenty-second he conquers what is beyond the sun, that is glory, that is freedom from sorrow.

CU 2.10 informs us that the seven-fold sāman has twenty two parts. The counting is done in terms of the syllables of the names of the seven parts of the sāman. Their individual syllable counts are 3, 3, 2, 3, 4, 4, 3, respectively. Although this division of the sāman is for the different parts of the song, the recursive system at the basis of Vedic narrative could suggest that it was also applied to notes. If that were the case, we find an exact match with the division of the śrutis for the gāndhāragrāma of Vedic music. We mention this to provide the musical foundation of Vedic thinking.

## Equivalence through Area and Number

We list the main units of measurement as described by Baudhāyana:

1 small pada = 10 aṅgulas
1 prādeśa = 12 aṅgulas
1 pada = 15 aṅgulas
1 īṣā = 188 aṅgulas
1 akṣa = 104 aṅgulas
1 yuga = 86 aṅgulas
1 prakrama = 2 padas
1 aratni = 2 prādeśas = 24 aṅgulas
1 vyāyāma = 4 aratnis
1 vyāma = 5 aratnis.

The rule that the gārhapatya and the āhavanīya are of one square puruṣa is mentioned in the Taittirīya Saṃhitā and Śatapatha Brāhmaṇa. The Śulbasūtras indicate that the gārhapatya, the āhavanīya, and the dakṣiṇāgni are all to have the area of one square puruṣa. In the agnicayana ritual the original āhavanīya altar later takes the place of the gārhapatya altar after the uttara vedi has been built. The Puruṣa is both a linear and an areal measure. As a linear measure it may be taken to be approximately the height of a man with his arms stretched upwards (say 2 meters), then as areal measure it is about 4 square meters.

The size of the altars is stated in ŚB 7.1.1.37 and 10.2.3.1 although there is a residual ambiguity in the text about the measure being used being linear or square. The gārhapatya represents the womb or the earth and it is thus circular whereas the āhavanīya is the sky, shown by the four cardinal directions, and it is represented by a square. The dakṣiṇāgni is a semi-circular figure.

The five layers of the mahāvedi altars were generally supposed to reach the height of the knee. Each layer in the falcon altar had 200 bricks leading thus to a total of 1,000 bricks in the five layers. It appears that the Ṛgveda knew of such an altar because the Puruṣa is described in RV 10.90 as "thousand headed, thousand eyed, thousand footed." In some cases ten or fifteen layers of bricks were prescribed. The basic falcon-shaped altar had an area of 7 1/2 square puruṣa. The body of the basic falcon-shaped altar was $2 \times 2$ (=4) square puruṣas, the wings and the tail were one square puruṣa each.

To make the shape look more like that of a bird, the wings were lengthened by one-fifth of a puruṣa and the tail was lengthened by one-tenth of a puruṣa. This defined the total area of 7 1/2 square puruṣas at the end of the first construction. On the second construction the area of the altar was increased by one square puruṣa to a total of 8 1/2 square puruṣas. Further constructions successively increased the area by one square puruṣa at each step until one came to the "one-hundred-and-one-[and-a-half]-fold" altar. In the construction of the larger altars the same shape as the basic altar is required and this requires solution of several geometric problems including that of the theorem of the diagonal. It is important to note that the altars are to be built in a sequence of 95.

The first step in abstraction requires a representation of a phenomenon through number. If two phenomena have the same number assigned to them then it is reasonable to seek connections between them. Thus a circadian biological cycle is to be linked, in a starting theory, to the earth's rotation. Likewise monthly periods are to be linked to the phases of the moon. Equivalence through number is to be found in the earliest Vedic texts and one would expect that it preceded the philosophy of equivalence through area.

In the Aitareya Āraṇyaka, the parallels between the planetary motions and man are thus drawn:

> Of bones, marrow, and joints there are 360 (parts) on (the right) side and 360 (parts) on (the left) side. They make 720 together, and 720 are the days and nights of the year. Thus the self which consists of sight, hearing, meter, mind, and speech is like the days. (AA 3.2.1.4)

> There are 360 syllables (vowels), 360 sibilants (consonants), 360 groups. What we call the syllables are the days, what we called sibilants are the nights, what we called groups are the junctions of days and nights... The syllables ... are physiologically the bones; the sibilants ... are the marrow; ... the groups are the joints. (AA 3.2.2.2-7)

## Agni, Rudra, and Prajāpati

Agni, the year, is also called Rudra (TS 2.2.10.4). Agni has three mothers (RV 7.59.12) which are earth, space, and sky. Rudra, similarly, has three mothers (ŚB 2.6.2.14). As symbols of time Agni and Rudra are couched in paradox. Thus Agni is the father of gods, although he is their son (RV 1.69.1); he is the bull who is also the cow (RV 10.5.7). ŚB 6.1.3.9-17 also symbolizes a year as Rudra, Śarva, Paśupati, Ugra, Aśani, Bhava, Mahādeva, and Īśāna. Śiva is sometimes represented collectively by the eight as Aṣṭamūrti. Rudra wields the thunderbolt (vajra) which is Indra's weapon. Agni and Indra are twin brothers (RV 6.59.2). Indra slays his father (RV 4.18.12) and likewise Rudra slays Dakṣa. These refer to the change in the reckoning of time brought about by a precession of the earth.[2]

Indra-Rudra or Śiva are sometimes represented by the world axis, the skambha. This is done for Indra even in our times when he is represented by a pole erected during the celebrations for the new year.[3]

The Śatapatha Brāhmaṇa speaks of the seven ṛṣis creating seven persons in the beginning, who are later assimilated into one person. This is represented by the fire-altar (Agni) who is Prajāpati, where the body represents four and the wings and the tail the other three (ŚB 6.1.1.5-6). Elsewhere (ŚB 10.6.4.1) Prajāpati is represented as a horse. This horse is also a metaphor for the sun. Aśvamedha sacrifice is to memorialize and to transcend time.

Prajāpati is a metaphorical representation of time and also of the year (ŚB 5.1.1.1). Time was represented by the constellations in the sky or the processes of life and death in the world. The fire altar is a symbolic representation of time in relation to man. According to Baudhāyana Śulbasūtra 7.17, the bricks can be replaced by mantras leading thus to the chandaścit. The year was represented by the Vedic stanza called bṛhatī, which consists of 36 syllables forming four verses divided into two hemistichs (8, 8, 12,

8) (ŚB 6.4.2.10). Elsewhere (ŚB 1.3.5.9) it is stated that by using 15 gāyatrī stanzas (of 24 syllables each) one obtains the days of the year and the year.

The fact that precession of the earth's axis caused the seasons to change slowly with time was expressed by myths like that of the decapitation of Prajāpati by Rudra. Due to the precession of the earth, Prajāpati, the year, marked by the sun rising in Orion at the vernal equinox, had moved toward Rohiṇī, his daughter.

Much earlier a similar passage was represented by the myth of Vṛtra being slain by Indra. Indra and Rudra represent the same frame of time at different epochs. Another similar myth is that of the creation of a new world with its own axis by Viśvāmitra.[4]

The identification of the year and man was carried on further than that of 360 days and 360 asthis. Śatapatha B. (12.3.2.5) speaks of the year having 10,800 muhūrtas (1 muhūrta = 48 minutes). Also note that 1 puruṣa = 120 aṅgulas and, therefore, the area of 7 1/2 sq. puruṣa for the basic altar equals 108,000 square aṅgulas.

The Ṛgveda had long spoken of Puruṣa (or Prajāpati) having a 1,000 fold nature. The year was therefore represented in terms of 5 layers of 200 bricks each. On the other hand, ŚB 7.4.2.31 explains that the 5 layers represent the 5 seasons of the year.

The most significant observation from the agnicayana ritual is that it described a 95 year cycle as represented by the altars going from the size of 7 1/2 square puruṣa to 101 1/2 square puruṣa. Since the epics and the Purāṇas ascribe the authorship of the Śatapatha Brāhmaṇa to Yājñavalkya (e.g. Mahābhārata 12.11739), we have called it the *Yājñavalkya cycle*.

## The Seven Ṛṣis and the Saptarṣi Era

The tradition of the seven ṛṣis, the stars of the Ursa Major, is ancient and it goes back to the Ṛgveda:

> Of those ṛṣis born together, they say that the seventh is born by himself, *saptatham ekajam*, while six are twins, God-born ṛṣis, *ṣaḷ idyamā ṛṣayo devajāḥ*. (RV 1.164.15; AV 9.9.16, 10.8.5)

While the ṛṣis are not named in the Ṛgveda, there is a mention of Viśvāmitra as being God-born, *devaja*, in RV 3.53.9. References in the Brāhmaṇas and the Upaniṣads suggest that the unpaired star is Atri which is $\epsilon$ Ursa Major, the fifth in order of listing of the stars of the group.

The Puruṣa Sūkta (RV 10.90) visualizes the cosmic giant Puruṣa who is the basis of the world. Later Prajāpati was viewed as a giant spanning the universe, framed by the constellations in the sky. Prajāpati was also the embodiment of the year (e.g. ŚB 6.1.2.19). BU 2.2.4 represents the seven ṛṣis as the lips of the cosmic person.

BU 2.2.4 speaks of these seven stars as representing the sense organs of the face of the cosmic person. Gautama and Bharadvāja are the ears, Viśvāmitra and Jamadagni are the eyes, Vasiṣṭha and Kaśyapa are the nostrils, and Atri is the tongue. That this identification was only general is borne out by the slightly different labeling in the ŚB 8.1.1.6-2.6 where Vasiṣṭha is speech, Bharadvāja is the mind, Jamadagni is the eye, and Viśvāmitra is the ear. This representation maps also the cognitive centers in the head as the seven ṛṣis.

The later texts present a terrestrial identification of the ṛṣis which parallels their mapping in the sky. As the political center of the Vedic Indians changed from the original region in the Northwest India, the geographical representation of some ṛṣ changed. This may be seen in the transition from the Vedic literature to the Epic literature and the Purāṇas, and it is in this manner that South India is associated with Agastya ṛṣi who is Canopus.

## On Intercalation

For ready reference note the following facts from modern astronomy:

Solar (sidereal) year = 365.25636 solar days
Solar (tropical) year = 365.24219 solar days
Moon's sidereal period = 27.32166 solar days
Lunar month = 29.530588 solar days = 30 tithis
Lunar year = 354.367 solar days
Tithis in a solar year = 371.06239

The solar year was known to be a little more than 365 days, although its nominal period was taken to be 360 days. TS 7.1.10.1-3 speaks of the 5 excess days over the Sāvana year of 360 days to complete the seasons, where 4 days are too short and 6 days are too long. TS 7.2.6.1 speaks of the extra 11 days, *ekādaśarātra*, over the 12 lunar months of 354 days required to complete the year.

That the reckoning was done both by the solar and the sidereal or nakṣatra counts is clear from the references to the year having 13 months (ŚB 7.1.1.32 or 7.2.3.9). Later books, such as the Nidāna Sūtras, speak clearly of the nakṣatra year being equal to 324 days which is 27 × 12. In a system of 28 nakṣatras the nakṣatra year equals 336 days. That Śatapatha Brāhmaṇa knows the nakṣatra year will be shown when we discuss the falcon altar again.

The eleven extra days in the solar year, when compared to the lunar year, were each assigned a separate god. A triple division of space and time is a common Ṛgvedic theme. Ṛgveda speaks of the three-fold world which then leads to a total of 33 gods. RV 7.87.5 speaks of three earths.

To get further information on the length of the solar year, one may use evidence regarding the extent of intercalation needed after the nominal year period of 360 days. Was the year taken to be 365 days or 366 days? With 366 days one would require intercalation of 12 days a year, whereas 365 days imply intercalation of 11 days. ŚB 10.5.4.5 describes the 756 bricks to be used in building the fire altar. These represent the 720 lunar days and nights followed by the 36 lunar days and nights in the intercalary month. This supports an intercalation of 18 days every 1 1/2 years.

Thus the basic year was taken to be 366 days, which would correspond to 372 tithis. But the ekādaśarātra also points to 365 days or 371 tithis. The only conclusion to be drawn is that the true length of the year was known to be between 365 and 366 solar days, or equivalently 371 or 372 tithis. This is corroborated by RV 4.33.7 we hear about the ṛbhus, the receptacles of time (RV 1.111.1; 4.34.9) who rest for 12 days after the year is over.

Further support for this is obtained from RV 3.9.9 which speaks of a total of 3339 gods in a year, personified as Agni. This corresponds to 371 tithis if one recognizes that in the Vedāṅga Jyotiṣa each tithi is equated to 9 bhāṃśas.

The period of 5 solar years was the basic yuga. These years were named saṃvatsara, parivatsara, idāvatsara, idvatsara, and vatsara (TS 5.5.7.3; ŚB 8.1.4.8) or minor variations of these names. A five year period was convenient because it led to two intercalation months of 30 tithis each, which the Vedāṅga Jyotiṣa evidence suggests were added at intervals of 2 1/2 years. But this would lead to an excess of about 4.688 tithis in 5 years, necessitating further corrections in greater periods.

The Taittirīya Brāhmaṇa (TB 3.9.22) calls the year the day of the gods. This indicates how increasing larger yugas were conceived.

## The 95 Year Yājñavalkya Period

ŚB 6.1.1.1-3 speaks of how the ṛṣis (here they are vital airs) created seven separate persons, who doubtlessly represent the seven cognitive centers. Now they made these seven persons into one person and this is represented by the seven (and a half) puruṣa altar. ŚB 10.2.3.18 now describes the process of building larger altars: "Prajāpati was created sevenfold in the beginning. He went on constructing (developing) his body, and stopped at the one hundred and one fold one." Later it is added that "the one hundred and one fold altar becomes equal to the seven fold one" (ŚB 10.2.4.4).

BSS 5.6 speaks of how the altar at the $m$th augmentation is obtained with the new unit $x$ after such augmentation satisfying $x^2 = 1 + (2m/15)$ where $m$ runs from 1 to 94. The 101 1/2 square puruṣa altar is obtained when $m = 94$ and for this $x^2 = 13\ 8/15$. Now ŚB 10.2.3.11 describes a "ninety-eight-fold" bird as having dimensions of 14 square puruṣa and Seidenberg[5] convincingly shows that this referred to the 101 1/2 square puruṣa altar.

The agnicayana ritual leads to a cycle of 95 years, as explained. The logic behind this cycle is that this leads to exactly 35 intercalary months (with a residual small error) in 95 years if the year is counted as 360 tithis. The intercalation is seven months in each subcycle of 19 years. The period of 95 years is basic also to the a nakṣatra year of 324 days. If each altar represent a yuga, the cycle becomes 475 years.

The use of the Yājñavalkya cycle at a later time is corroborated by the creation of the 2850 year cycle in the Romakasiddhānta, which is 30 × 95, or a "month" of such a cycle.

## More on Altar Design

ŚB 10.4.4.2 speaks of the number of stars in the sky being equal to the number of muhūrtas (1 day = 30 muhūrtas) in 1,000 years or $1000 \times 360 \times 30 = 10,800,000$. This is followed by consideration of muhūrta as a basic measure in the consideration of the grand year of 1,000 ordinary years. A muhūrta is to a day what a day is to a month. In other words the grand year consists of 10,800,000 units, which were presumably taken to correspond to years.

The important gārhapatya altar, that represents earth or the womb, has an area of 1 square puruṣa which equals 14,400 square aṅgulas. This requires drawing a circle around a square of side one vyāyāma (1 vyāyāma = 4/5 puruṣa). It is constructed with 21 bricks in each layer (ŚB 7.1.1.34). With 7 1/2 square puruṣa considered equal to 360 days, the area of the gārhapatya altar equals 48 days.

Note also that the falcon altar symbolizes all the three years: nakṣatra, lunar, and solar. The increase in the area in each new construction of the falcon altar is one square puruṣa which equals 48 days. The purpose of the increase is to make the altar become closer to the actual year. If the nakṣatra year is now taken to be 324 tithis, the additional 48 tithis are needed to make it exactly equal to the nominal year of 372 tithis. On the other hand, it may indicate the size of a larger yuga by the following correspondence:

1 tithi = 9 bhāṃśas like 1 year (371 tithis) = 3339 bhāṃśas;
48 days expands to a larger period of $48 \times 9 = 432$.

This multiplier of 9 may have also been used in going from 12 months to a period of 108.

The expansion of 48 tithis is required every year for it is clearly stated that the expanded altar is to be viewed with Prajāpati the year. Since we do know that the number of tithis in a year is 371.06239, this implies an excess of 0.93761 tithis per year. In 95 years this excess would be almost exactly equal to 89 tithis. It appears that the period of 95 years was chosen because observationally the excess was taken to be 90 tithis or 3 lunar months. Every 95 years a major adjustment of the calendar was then required. This also means that the adopted solar year was 372 - 90/95 = 371.05263 tithis, which corresponds to 365.24675 days. This is quite close to the tropical year of 365.24219 days and it is quite possible that such a year was meant.

One may assume that the altar ritual came to have its fundamental importance by expressing significant astronomical knowledge regarding the incommensurability of the solar and the lunar years, as hinted by the statements that agnicayana is not only ritual but also knowledge. The observations were made over centuries and a calendrical system of reckoning existed. It appears that the Saptarṣi centennial reckoning was this system.

It is natural to speculate on what other astronomical observations were made by the Vedic ṛṣis. Planetary motions must have been tracked but these motions was not the basis for fixing the year.

Remembering that the altars are mentioned in the Ṛgveda in connection with early ṛṣis and kings, the astronomy of the fire altars is early Vedic knowledge. We show in the next chapters that by the time the Ṛgvedic era closed the knowledge of the planetary periods was also established.

## Solstice Days in the Vedic Literature

We consider two early Brāhmaṇas, Aitareya and Kauṣītaki, to provide corroboration to the premise of careful astronomical observations. The Aitareya Brāhmaṇa 4.18 says:[6]

> They perform the ekaviṃśa day, the viṣuvant (the summer solstice), in the middle of the year; by the ekaviṃśa the gods raised up the sun to the world of heaven; it is here the eksviṃśa; below this divākīrtya are ten days, ten above; in the middle is the ekaviṃśa resting on both sides in the virāj (a period of ten days), for on both sides he finds support in the virāj. Therefore going between these worlds he does not shake.
>
> The gods were afraid of this Āditya (the sun) falling down from the world of heaven; him with three worlds of heaven from below they propped up; the three worlds of heaven are the stomas. They were afraid of his falling away up; him with three worlds of heaven from above they propped up; the three worlds of heaven are the stomas. Thus below there are three saptadaśa stomas, three above; in the middle is the ekaviṃśa.

Thus Vedic astronomers took the sun to remain practically stationary for 21 days near the summer solstice. This period of 21 days included ten days of northernly motion and ten days of southernly motion, the middle (eleventh) day was the day of the summer solstice. We cannot say if this number of 21 was chosen to reflect the earth number.

The reference to the propping up with three saptadaṣa stomas on either side of the solstice day apparently defined the interval of 51+51 = 102 days, excluding the solstice day. Together with 78 days of the atmosphere, these then define the nominal half-year of 180 days.

The Kauṣītaki Brāhmaṇa (19.3) speaks of the time of the winter solstice:[7]

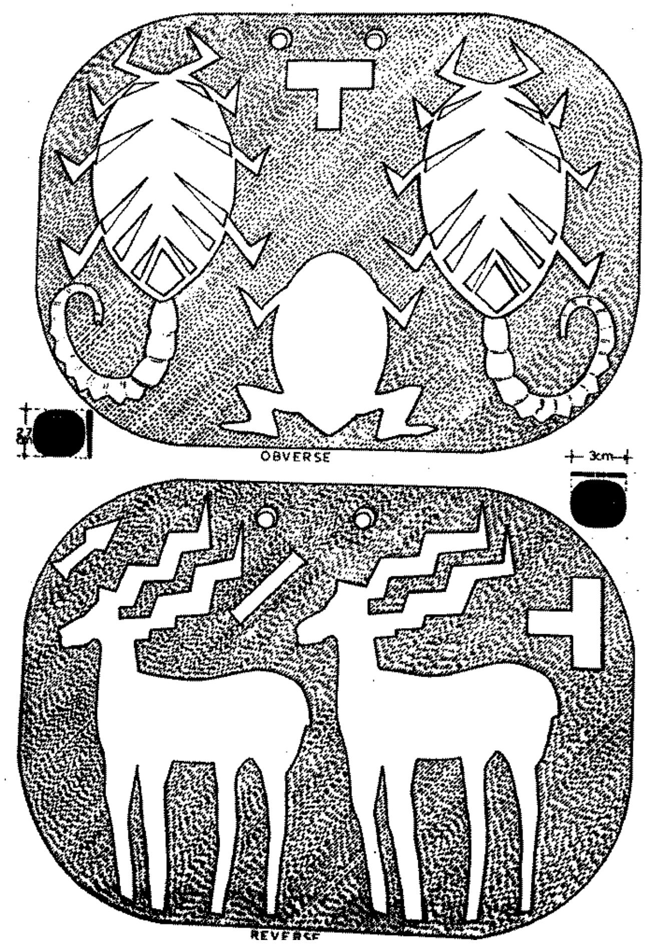



Figure 4.5: Decapitation of Orion: a 3rd millennium seal

> On the new moon of Māgha he (the sun) rests, being about to turn northwards; these also rest, being about to sacrifice with the introductory atirātra; thus for the first time they obtain him; on him they lay hold with the caturviṃśa; that is why the laying hold rite has this name. He goes north for six months; him they follow with six day periods in forward sequence. Having gone north for six months he stands still, being about to turn southwards; these also rest, being about to sacrifice with the viṣuvant day; thus for the second time they obtain him. He goes south for six months; him they follow with six months periods in reverse order. Having gone south for six months he stands still, being about to turn north; these also rest, being about to sacrifice with the mahāvrata day; thus for the third time they obtain him. In that they obtain him thrice, and the year is in three ways arranged, verily it obtains the year. With regard to this the sacrificial verse is sung:
>
> *Ordaining the days and nights*
> *like a cunning spider*
> *for six months south constantly*
> *for six north the sun goes.*
>
> For six months he goes north, six south. They should not consecrate themselves at this time. The corn has not arrived, the days are short, shivering they come out from the final bath. Therefore they should not consecrate themselves at this time. They should consecrate themselves one day after the new moon of Caitra; the corn has come, the days are long, not shivering they come out from the final bath. Therefore that is the rule.

The reference to the winter solstice on the new moon of Māgha demonstrates that the calendar was defined with respect to the lunar months as well as the solstices or the solar year. It is the harmonization of this dual reckoning that we saw in the design of the altars.

Before closing we mention a 3rd millennium seal from Rehman Dheri, showing a pair of scorpions on one side and two antelopes on the other, that suggests a knowledge of Vedic themes (Figure 4.5).

It was suggested that this seal represents the opposition of the Orion (Mṛgaśiras, or antelope head) and the Scorpio (Rohiṇī) nakṣatras. The arrow near the head of one of the antelopes could represent the decapitation of Orion. The interpretation of the Prajāpati/Rudra myth as representing the shifting of the beginning of the year away from Orion places the astronomical event in the fourth millennium BCE.

# 5. *The Architecture of the Ṛgveda*

## Books and their Authors

According to tradition, the Ṛgvedic hymns, assembled by Paila under the guidance of Vyāsa, formed the Saṃhitā and the authors of the Brāhmaṇa literature described and interpreted the Vedic ritual. Yāska was an early commentator of the Ṛgveda and he discussed the meanings of many difficult words. In the 14th century, Sāyaṇa wrote an exhaustive commentary on it.

A number of other commentaries were written during the medieval period, including the commentaries by Skandasvāmin (roughly of the Gupta period), Udgītha, Venkaṭa-Mādhava (ca. 10th to 12th century) and Mudgala (after Sāyaṇa who did an abbreviated version of Sayana's commentary).

Vyāsa assembled the hymns of the Ṛgveda out of the many circulating at the time. We are interested in determining the logic that was used by him to assemble the collection. This would not only throw light on the collection but also reveal attitudes about the world and the sciences that existed at that time. Specifically, we hope to find the organization of the text based on the cosmology of the Vedic system. Traditionally, scholars have only wondered about the hymn counts of Books 1 and 10 being the same. In this chapter we will show the deeper order of the text.

To study the design of the Ṛgveda it is essential to make a distinction between its index tradition and the text itself. It is also essential to recognize that in spite of the astonishing fidelity with which the Vedic text has been passed down, the same fidelity may not be true for the index tradition.

There are many references to the larger plan of the texts. ŚB 10.4.2.23-24 describes that the Ṛgveda has 432,000 syllables; The Yajurveda has 288,000 and the Sāmaveda has 144,000 syllables.

These round numbers are ample evidence indicating a numerical principle at work in the design of the texts. The syllable count of the canonical text of the Ṛgveda has only 394,221 syllables, however.[1] This syllable count is for the Saṃhitāpāṭha where sometimes syllables in sequence coalesce due to rules of sandhi. But this suggests that there could be a difference between the "ideal" syllable count and the actual count of the syllables.

The Ṛgveda Prātiśākhya 17.14 explains: "To get the correct count for the total, resolve the coalesced combinations in the incomplete pādas." Thus Raster[2] shows how the syllable count of the first hymn, which has 9 verses in the gāyatrī meter, can be restored from its actual 210 to the correct 216 which is $9 \times 24$.

When the correct count for all the meters is made the syllable count increases to 394,317. However, such exercises are somewhat futile in estimating the size of the Ṛgveda because the meters can be defined in a variety of ways and this restoration would then depend on the description of the meters in the less reliable index tradition.

According to Śaunaka's Anuvāka Anukramaṇī, the Ṛgveda of the Śākala recension consists of 1017 main hymns, divided into 10 maṇḍalas (books) of varying lengths, and an appendix of 11 khila hymns that are called the Vālakhilya hymns.[3]

The Bāṣkala recension, according to Śaunaka, consisted of 8 more hymns, but this recension has not survived. It is believed that the 8 additional hymns of the Bāṣkala recension consisted of 7 Vālakhilya hymns and the Saṃjñāna hymn. In other words, the two recensions differ only in the arrangement of the khilas. This fact also suggests that the various recensions referred in the Purāṇas might have had very little differences.

The Anukramaṇīs ascribe books 2 to 7 to the ṛṣis Gṛtsamada, Viśvāmitra, Vāmadeva, Atri, Bharadvāja, and Vasiṣṭha or their families respectively. Book 9 is a collection of hymns by several ṛṣis to Soma Pavamāna, or Soma poured through the filter. Book 1 which consists of 191 hymns is classed into 15 groups of hymns by different ṛṣis. Book 10 also has 191 hymns and its first 84 hymns are classed into 25 groups based on ṛṣis, and its remaining 107 hymns are counted singly. The Anukramaṇīs give the authorship for the individual hymns, but we will not have occasion to analyze that information in this book.

The classification of the family books 2 to 7 is based on hymns to different gods and these groups are 5, 4, 11, 7, 5, 12 respectively. Book 8 hymns are grouped according to the particular ṛṣis of the

Kaṇva family. Including the Vālakhilya hymns these constitute 19 groups. The hymns of Book 9 are grouped into 7 according to the meter. These meters are gāyatrī, jagatī, triṣṭubh, anuṣṭubh, uṣṇiḥ, pragātha, and miscellaneous. These hymns are by a host of ṛṣis including Bhṛgu, Kaśyapa, and Kavi Uśanas. This information is summarized in Table 5.1.

Table 5.1: Hymns and groups

| Maṇḍalas | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Hymns | 191 | 43 | 62 | 58 | 87 | 75 | 104 | 92 | 114 | 191 |
| Groups | 15 | 5 | 4 | 11 | 7 | 5 | 12 | 18 | 7 | 132 |
| Anuvākas | 24 | 4 | 5 | 5 | 6 | 6 | 6 | 10 | 7 | 12 |

We see that the number of hymns in the different books (maṇḍalas) satisfies the following relationships:

Books [1+2+3+4] = 354 (Lunar year)
Books [4+7] = Books [5+6] = 162 (1/2 Nakṣatra year)
Books [4+5+6+7] = 324 (Nakṣatra year)
Books [6+7] = Books [5+8] = 179
= 1/2 Books [1+6+8] = 1/2 Books [5+6+7+8]
Books [5+7] = Book [1] = Book [10]

Note further,

1/2 nakṣatra year + 21 = 1/2 year of 366 days.

The number of hymns in Books 1 and 10 is 191 each. This number satisfies the interesting equality:

191 = 113 + 78

where 113 is one ninth of the total number of hymns in the Ṛgveda and 78 is the atmosphere number of the fire altars. These relationships highlight their astronomical basis.

The Anuvāka Anukramaṇī says that the total number of Anuvākas is 85, the number of adhyāyas is 64, and the number of vargas is 2,006. The total number of verses is declared to be 10,580 1/2; the number of half-verses is 21,232 and of the words 153,826. According to Ṣaḍguruśiṣya the half verse comes from RV 10.20.1. Śaunaka also declares that the number of syllables is 432,000.

How is one to explain the discrepancy between the numbers of Śaunaka and that of the canonical text? One cannot assume that the canonical text is much smaller than the text available to

Śauanka because there exists perfect agreement in the number of hymns, the meters of the various verses, and so on. The average per verse based on Śaunaka's verse numbers should be 40.83 to yield the syllable count of 432,000. The actual average is however 37.65 because although triṣṭubh (44 syllables) is the most common meter, the second most common meter is gāyatrī (24 syllables).

The only conclusion that is open to us then is that the number 432,000 is the ideal number of syllables. Considering that RV 1.164.45 declares that speech is of four kinds, three of which are unmanifest, then the shortfall of 37,779 syllables must be in terms of unmanifest syllables.

## The Ṛgvedic Index Related To The Other Vedas

### Sāmaveda

The two main extant recensions of the Sāmaveda are Kauthuma (considered the vulgate) and the Jaiminīya; a third recension called the Rāṇāyanīya is very similar to Kauthuma.

The Kauthuma recension consists of 1810 verses in two main books called the Pūrvārcika (585 single verses) and the Uttarārcika (1225 verses); in addition there are 54 verses in the Āraṇyaparvan which belongs to the Pūrvārcika, which in turn has an appendix of 11 mahānāmnī verses. The mahānāmnī verses may also be found in the fourth Āraṇyaka of Aitareya Āraṇyaka. Altogether, therefore, the recension has 1875 verses.

### Yajuraveda

According to tradition there were 101 schools of the Yajurveda in two groups, viz., Kṛṣṇa and Śukla. The surviving texts of the Kṛṣṇa Yajurveda are placed into four main groups: Taittirīya, Kāṭhaka, Kapiṣṭhala, and Maitrāyaṇīya.[4] The Taittirīya has the best preserved texts. The Śukla or the Vājasaneyi Yajurveda is represented by the Mādhyandina and the Kāṇva recensions.

The Vājasaneyi Yajurveda[5] is organized in a more regular fashion. It appears that out of its 40 chapters the first 18 form the core text; chapters 19-25 deal with sautrāmaṇi and aśvamedha sacrifices; chapters 26-35 are called khilas or supplementary material; chapters 36-39 are devoted to the pravargya ceremony and chapter 40 is the Īśa Upaniṣad. The total number of verses has been taken to be 1,975 or 1,984. The first 18 chapters add up to 1,026 verses.

**Atharvaveda**

There are two extant recensions: the Paippalāda and the Śaunakīya. The Śaunakīya recension is much better preserved; it consists of 20 books of which the first 18 appear to be the core. Book 19 has material arranged differently from the preceding books and book 20 is clearly supplementary. It will be shown later that the core text consisted of 5,226 verses. According to Satvalekar the verse total for the entire text is 5,977; the Paippalāda recension has about 8,000 verses.

## Analysis Of Hymn Numbers

We begin with the analysis of the number 432,000. ŚB 10.4.4.2 speaks of the number of stars in the sky being equal to the number of muhūrtas (1 day = 30 muhūrtas) in 1,000 years or $1000 \times 360 \times 30 = 10,800,000$. This means that the ideal number of syllables in the Ṛgveda equals the number of muhūrtas in 40 years. The number of days in 40 years is 14,400 and if one took the identity of a day to a verse then this would be the number of verses in the Ṛgveda.

The average number of syllables per verse is therefore 30, or the mean of gāyatrī and bṛhatī. Now we know that sky (or heaven) is ascribed the number 261 in Vedic ritual. If we consider the equation that the verse is to the sky-day what the syllable is to the muhūrta, then the number of verses in a span of 40 years, considering 261 sky days per year, equals 10,440. This is only two less than the actual count obtained by Macdonell,[6] and it appears that the canonical text had two fewer verses by reorganizing, say, four shorter verses into two longer ones.

As argued by Macdonell his count of 10,442 for the Ṛgveda verses may be reconciled with Śaunakas's figure by considering the 127 dvipadās twice; this raises the count to 10569 verses which is only 11 verses less than Śaunakas's figure. It is possible that the 11 hymns of the khila were counted as the remainder in a count across categories, evidence of which is common as in the number 17 counted as 12 months and 5 seasons in the brāhmaṇas.

One can propose another theory that the Ṛgveda is ideally 10,800 verses with an average of 40 syllables per verse. The shortfall between this number and the actual of 10,440 is exactly 360 verses. Since 10,800 are the muhūrtas in one year, the shortfall amounts to the muhūrtas in 12 days.

We now come to another theory for the reconciliation of the verse count of 10,580 to the actual count of 10,440. We propose that the khila verses originally totalled 140, that is 60 more than the current number. But such a possibility is unlikely since there is no tradition that speaks of such a large number of lost verses.

We can also explain the significance of the actual count of syllables. Knowing that the earth number is 21 and the sky number is 261, it is likely that the actual syllables are 240/261 of the ideal number of 432,000. This amounts to 399,241 syllables. Now the count of syllables for the Ṛgveda and the khila verses is 397,265. Therefore, there must have been a modification suggested by actual observations.

How do we explain the number 10,442 as the verse count in the Ṛgveda? It appears that the knowledge that the year was actually 371.05 tithis was translated into a representation of the sky number to 261.05. Over 40 years now we get 10,442 verses. If the other numbers are proportionately changed to 77.96 and 20.99, then the ratio

$$240.06 \times 432,000/261.05 \;=\; 397,265.$$

This is precisely the number of syllables of the Ṛgveda.

One may further assume that when the Ṛgveda expanded from its core size of 10,440 verses, 2 more verses were added to it. Paralleling this, 2 verses were added to the 78 original khila verses.

We assume that the logic of considering the muhūrtas of 40 years to represent the syllables of the Ṛgveda flows from the time span of 100 years to represent all the four Vedas. As explained above, Yajur and Sāmaveda taken together also get 40 years; the remaining 20 years are assigned to the Atharvaveda. That such a logic was at work is suggested by the fact that the total number of hymns in the Śaunakīya recension, when considering only the Kuntāpa hymns of the Book 20 is 5,226, just six more than the number of hymns according to this theory.

The total number of hymns in the Śaunakīya recension when the remainder of the Book 20 is also considered is 5977 which equals $43 \times 139$.

The distribution of all the verses of the Vedas as they have come down to us is:[7]

Table 5.2: Verses in the Vedic books

| | |
|---|---|
| Ṛgveda | 10522 |
| Yajurveda | 1984 |
| Sāmaveda | 1875 |
| Atharvaveda | 5977 |
| Total | 20358 |

That this total is exactly $261 \times 78$ implies that the verses were, metaphorically, supposed to pervade the entire space of span 78 and breadth 261.

One might assume that the original structure started with $261 \times 40 = 10,440$ verses for the Ṛgveda corresponding to 40 years; the Atharvaveda had $261 \times 20 = 5,220$ verses for 20 years. The Yajurveda and the Sāmaveda were assigned approximately 80 and 40 years, which arose from the space number of 78 and by its half 39. Also we believe that the Śatapatha Brāhmaṇa reference to the verses of the Yajurveda and Sāmaveda being in the proportion 2:1 is only approximately true; the correct proportion being 25:15.

This leads to the figure $78 \times 25 = 1,950$ verses for the Yajurveda and $39 \times 15 = 585$ verses for the Sāmaveda.

The figure for Yajurveda is very close to the value leaving out the Īśa Upaniṣad verses of chapter 40 and the Sāmaveda figure is identical to the Pūrvārcika verses. Various considerations, like the ones for the Ṛgveda verse totals outlined earlier, led to modifications of these numbers with the constraint that the total had to be $261 \times 78 = 20,358$.

Other numerical and astronomical considerations played a role in the modifications that were introduced. Is it possible that the Atharvaveda number was first increased to 5,226 because it is $78 \times 67$?

From another perspective, we expect that the syllable count for the Sāmaveda by the Śatapatha Brāhmaṇa reference comes to 4,800 verses and that for the Yajurveda to 9,600 verses. Now note that the 585 Pūrvārcika stanzas are in practice sung to double the number of tunes; this allows us to modify the total count as $1,225 + 2 \times 585 + 54 + 11 = 2,395$.

This is just 5 short of the half of the total 4,800. Considering still another angle, note that Sāmaveda has 1810 verses plus 5 hymns in the Āraṇyaparva and the 11 mahānāmnī verses. If we add across categories we get a total of 1826, only one less than $261 \times 7$.

The basis behind the verse totals was forgotten quite early since there is no mention of it in the various Anukramaṇīs. But it survived in certain circles as evidenced by its use in the Bhagavadgītā. The fact that the numbers, after the passage of millennia, still satisfy the number relationships further attests to the amazing fidelity with which the texts were preserved.

# 6. *The Ṛgvedic Code*

## The Ṛgvedic Book Numbers

The Ṛgvedic book numbers and hymn totals define a set of 20 numbers. Are these numbers, and the sequence in which they are defined, accidental or is there a deliberate plan behind the choice? The answer to this question is obtained by examining these numbers in relation to other data and by determining if they have any structure. The previous chapter made the case that these numbers had a plan underlying them. We mentioned that the texts themselves spoke of a relationship of the total verses and certain time durations.

One would expect that if the Ṛgveda is considered akin to the five-layered altar described in the Brāhmaṇas then it ought be associated with numbers associated with the altar ritual. We have seen that these numbers are from the count of 360 (the length of the nominal year) and its division into 21 (earth), 78 (atmosphere), and 261 (sky).

My discovery that the Ṛgveda is an altar of mantras came rather suddenly. Although I had been studying the altars described in the Śatapatha Brāhmaṇa for several months, I had never thought of any connection of these with the Ṛgveda. It was while reading some unrelated matter the idea flashed that the Ṛgveda itself is a symbolic altar.

The idea came that the first two books should correspond to the space intermediate to the earth and the sky, and since the number that represents space is 78 the first two book numbers should be related to it. When used with the multiplier of 3 for the three worlds, the space number is a total of 234 hymns. Now 43 is an important number related to the Śri Cakra, and it is possible that the other number 191 is simply 234-43. The yantra of the Śvetāśvatara Upaniṣad 1.4 appears to be this Cakra.

The number of hymns in the first two books is 191 and 43.

One may represent the Ṛgvedic books as a five-layered altar of books as shown in Table 6.1, with two books assigned to each layer.

Table 6.1: The altar of books

| | |
|---|---|
| Book 10 | Book 9 |
| Book 7 | Book 8 |
| Book 5 | Book 6 |
| Book 3 | Book 4 |
| Book 2 | Book 1 |

When the hymn numbers are used in this altar of books we obtain Table 6.2, and the structure of the arrangment starts to reveal itself.

Table 6.2: Hymns in the altar of books (Altar 1)

| | |
|---|---|
| 191 | 114 |
| 104 | 92 |
| 87 | 75 |
| 62 | 58 |
| 43 | 191 |

We may represent the altar arrangement of Tables 6.1 and 6.2 by the book sequence

2-1 3-4 5-6 7-8 10-9 [Altar 1]

in the five layers counting from bottom up and left to right. The choice of this arrangement is prompted by the considerable regularity in the hymn counts. The hymn count separations diagonally across the two columns are 29 each for Book 4 to Book 5 and Book 6 to Book 7 and they are 17 each for the second column for Book 4 to Book 6 and Book 6 to Book 8. Books 5 and 7 in the first column are also separated by 17; Books 5 and 7 also add up to the total for either Book 1 or Book 10.

Figure 6.1 captures these relationships as a graph with several symmetries. It is quite evident that these symmetries couldn't have arisen out of chance.

Another regularity is that the middle three layers are indexed by order from left to right whereas the bottom and the top layers are in the opposite sequence.[1] This arrangement puts Books 1 and 10 in different columns, providing balance to the numbers.

Furthermore, Books [4+6+8+9] = 339, and these books may be taken to represent the spine of the altar. The underside of the

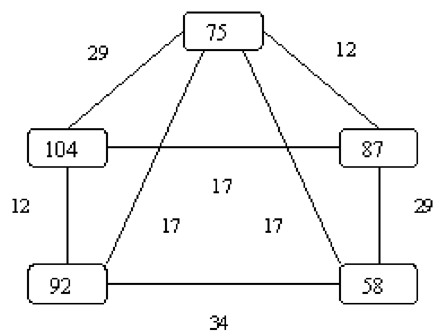



Figure 6.1: Ṛgveda Books 4-8 as a graph

altar now consists of the Books [2+3+5+7] = 296, and the feet and the head Books [1+10] = 382. The numbers 296 and 382 are each 43 removed from the fundamental Ṛgvedic number of 339.

Now we investigate the other natural choices for comparison. Based on considerations of symmetry, these choices are:

1-2 3-4 5-6 7-8 9-10 [Altar 2]

1-2 4-3 5-6 8-7 9-10 [Altar 3]

Altar 2 has the books arranged in the same order across the layers, whereas Altar 3 has the books arranged in alternating order across the layers. Altars 2 and 3 yield the following set of numbers for the underside, the spine, and the feet and the head:

268 367 382 [Altar 2]

284 351 382 [Altar 3]

These numbers have no apparent order which leads one to conclude that Altars 2 and 3 were not the actual designs.

The Brāhmaṇas and the Śulbasūtra tell us about the altar of chandas and meters, so we would expect that the total hymn count of 1017 and the group count of 216 have particular significance. Owing to the pervasive tripartite ideology of the Vedic books we choose to view the hymn number as $339 \times 3$. The tripartite ideology refers to the consideration of time in three divisions of past, present, and future and the consideration of space in the three divisions of the northern celestial hemisphere, the plane that is at right angle to the earth's axis, and the southern celestial hemisphere.

One may argue that another parallel with the representation of the layered altar was at work in the group total of 216. Since the altar of hymns was meant to symbolically take one to the sky, the abode of gods, it appears that the number 216 represents twice the basic distance of 108 taken to separate the earth from the sky. The Ṛgvedic code then expresses a fundamental connection between the numbers 339 and 108.

In the cosmic model used by the ancients, the earth is at the center, and the sun and the moon orbit the earth at different distances, and this model is at the basis of the earliest Indian astronomy as well. why was the number 108 taken to represent symbolically the distance between the earth and the sky? The answer is provided by the actual distances to the sun and the moon.

The number 108 is roughly the average distance that the sun is in terms of its own diameter from the earth; likewise, it is also the average distance that the moon is in terms of its own diameter from the earth. It is owing to this marvelous coincidence that the angular size of the sun and the moon, viewed from the earth, is about identical.

It is easy to obtain this number. The angular measurement of the sun can be obtained quite easily during an eclipse. The angular measurement of the moon can be made on any clear full moon night. A easy check on this measurement would be to make a person hold a pole at a distance that is exactly 108 times its length and confirm that the angular measurement is the same. Nevertheless, the computation of this number would require careful observations. Note that 108 is an average and due to the ellipticity of the orbits of the earth and the moon the distances vary with the seasons. It is likely, therefore, that observations did not lead to the precise number 108, but it was chosen as the true value of the distance since it is equal to $27 \times 4$, where the mapping of the sky into 27 nakṣatras has already been described.

The second number 339 is simply the number of disks of the sun or the moon to measure the path across the sky:

$\pi \times 108 \approx 339.$

This represents an early approximation to $\pi$ that takes it equal to 3.1389.

Figure 6.2 presents the approximate separations between the sun, the earth, and the moon based on modern astronomical values. The knowledge that the sun was 108 units away from the earth was expressed by taking the length of the axis from the gate to the main altar to be 54 units (half of 108) and the perimeter to be 180 (half of the annual circuit of 360 days)(Figure 6.3).[2]

To see the plan of the temple, we draw the Agnikṣetra within a rectangular area. It is appropriate here to be guided by the proportions that are clearly spelt out, such as that of 1:2 for the Prācīnavaṃṣa, as also by numbers that are in terms of the meter numbers, which are used in a parallel representation of the altar. Amongst the meters, gāyatrī (24) is the head, uṣṇiḥ (28) the neck, anuṣṭubh (32) the thighs, bṛhati (36) the ribs, paṅkti (40) the wings, triṣṭubh (44) the chest, and jagatī the hips; virāj (30) is invoked in the description of the Mahāvedi.

It appears that for accord with the measures which are multiples of 6, the left area was increased by an additional one unit to the west to become 24 × 30 as in Figure 6.2, which is described as an appropriate proportion for a house in later texts such as Varāhamihira's Bṛhat Saṃhitā (53.4) indicating that it is an old tradition. The Prācīnavaṃṣa's share to the perimeter is $24 + 30 + 24 = 78$, which is the atmosphere number. This is also in accord with the notion that the Prācīnavaṃṣa is tripled in size in the completion of the Mahāvedi, going from 10 × 20 to 30 × 60.

The basic temple plan has the overall dimensions 60 × 30, with a perimeter of 180. The overall temple proportion of 1:2 is attested in later texts such as the Bṛhat Saṃhitā and Śilpa Prakāśa.

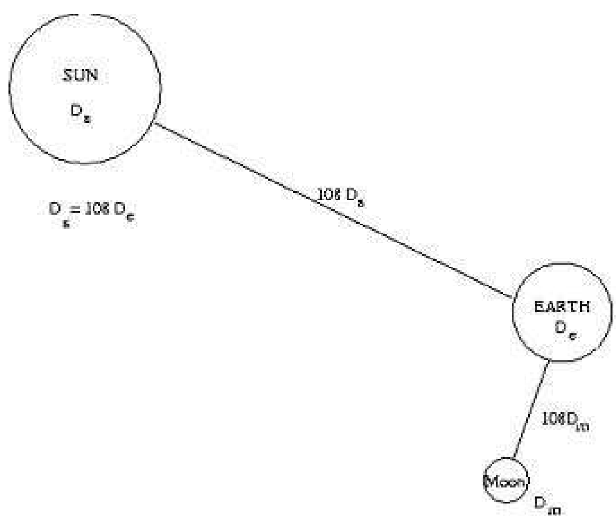



Figure 6.2: Approximate Sun, Earth, Moon distance ratios

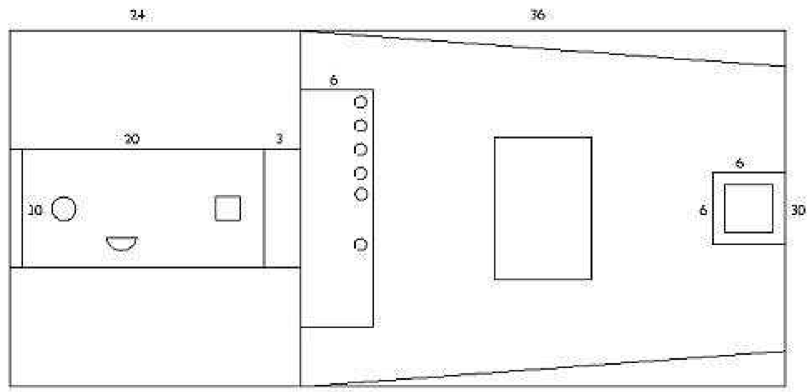



Figure 6.3: Axis and perimeter of the temple

Once 108 was arrived at 339 could be easily calculated. These estimates were refined through mutually related measurements. For example, one counted the number of disks of the sun or the moon that went into an arc of a specified extent. If the relationship between radius and circumference was not known then one required more refined observation of the number of sun or moon disks.

For further circumstantial evidence supporting an astronomical interpretation for the numbers 108, 339, and 78, consider that the year of 366 days was divided into two equal parts of 183 days, the uttarāyana and the dakṣiṇāyana, where the uttarāyana was taken to belong to the gods. The 339 steps of the sun were now reconciled with the 183 count of the gods by postulating a space count of 78, since $339 = 183 + 2 \times 78$. This is the same mapping seen in the altar construction of the Śatapatha Brāhmaṇa that was mentioned earlier.

We return to a further examination of the numbers 296, 339, and 382 in the design of Altar 1. We propose that since 339 has an obvious significance as the number of sun-steps during the average day or the equinox, the other numbers are likely to have a similar significance. We suggest that 296 is the number of sun-steps during the winter solstice and 382 is the number of sun-steps during the summer solstice.

Let us evaluate this proposal. Since the number of sun-steps represent the length of the day, we have a ratio for the longest to the shortest day which is equal to $382/296 = 1.29$. We know that the hymns of the Ṛgveda were composed in the region of the

Dṛṣadvatī and the Sarasvatī rivers which flow in the latitudes of 30° to 22°. If we accept the tradition that Kṛṣṇa Dvaipāyaṇa Vyāsa arranged the hymns into the current form, then again we must accept the same region for his work. Do the facts square up with this interpretation of the numbers 296 and 382.

The length of the day varies with the latitude. If $\theta$ is the latitude of the place of observation and $\phi$ is the inclination of the earth's axis to its orbit, then the ratio $R$, the duration of the longest day divided by the duration of the shortest day, for a spherical earth on a circular orbit and without an atmosphere is given by:

$$R \ = \ cos(\theta - \phi)/cos(\theta + \phi).$$

This figure needs correction because of the flattening of the earth and since refraction causes the sun to rise earlier and set later than it would if the earth had no atmosphere. This refraction causes the duration of daylight to be extended by about 6 or 7 minutes at the expense of the duration of darkness. This necessitates a correction of about 2° from the value obtained by the above equation.

Now consider $\phi$, the obliquity of the ecliptic. Although its current value is about 23.5°, it is believed to vary slowly between about 24° and 22°. According to one estimate it changes about 47 seconds in a century. Considering that the settlements on the Sarasvatī were in their golden age in the third millennium B.C.E., a further error of about 1° could have been caused by changing $\phi$.

Considering refraction effects one obtains a value of $R = 1.2929$ for the latitude of 22°. With a further correction for $\phi$ and noting that it was smaller than the current value, this value may be revised to about 23°. The latitude of 23° passes through Gujarat close to where Sarasvatī emptied into the sea.

Lagadha in the Vedāṅga Jyotiṣa speaks of the ratio of the longest to the shortest day being 1.5. After corrections are made, this corresponds to a latitude of 34° which is correct for Northwest India to the north of the Sarasvatī valleys. Since the Vedāṅga Jyotiṣa was composed after the early Ṛgvedic age when the focus of the civilization had passed east to the Yamunā-Gaṅgā region and west to upper Indus region, the figure of 34° accords with this sequence.

If one accepts the interpretation of the Ṛgvedic code sketched above, two further possibilities need to be examined. Was the ratio of 382/296 a precise value reflecting the region where Sarasvatī met the sea or was the value obtained after adjustment made in consonance with a theory?

We speculate that the figure was arrived at indirectly in the following fashion. TS 7.2.6 speaks of how the seasons were born of the ekādaśarātra rite. Now the birth of seasons implies a shortening and lengthening of days. For two such rites at the two solstices leaves us with a total of 366-22=344 days. From the winter to the summer solstice this implies a total of 172 days. Since the lengthening was a total of 86 sun-steps, a growth of half a sun-step each day was assumed. If this is what happened then the latitude of 23° that we arrived at was a rough value true for any of the general region of the Sarasvatī valleys. Note also that a linear model of shortening and lengthening of days is assumed in the Vedāṅga Jyotiṣa as well.

To return to the Ṛgvedic code one can think of various theories to tie the numbers to possible astronomical observations. For example, the primary observation number may have been 339 from which the other two numbers were derived by subtracting and adding 43. The number 339 could be found through a geometric construction once the distance that the sun is 108 sun diameters away from the earth was agreed upon. It is also clear that all these numbers were cross checked through independent measurements.

Note that the figure of 339 could be obtained during day or night by determining the sun or moon-steps over a certain arc. Such a process would require time-keeping and if water clocks were used then the temperature variation over different parts of the day and night would introduce errors. The progress of time during night could be measured by the nakṣatras rising in the night sky but again refraction and flattening of the earth would introduce errors.

It is also plausible that the sun-steps were measured for the winter and the summer solstices and the average value taken to represent the equinox number.

Why did the brick altars use 1,000 bricks? Is it because 1,000 solar days equal 1,017 tithis almost exactly? If this was the case then it is supportive of the representation of the lunar year by 360 tithis. But there could be other reasons such as 1,000 being a large number that denotes infinity.

## Planetary Periods from the Ṛgvedic Code

It is certain that planets were known in the Ṛgvedic period but since this knowledge was not of significance in calendrical concerns, texts like the Vedāṅga Jyotiṣa had no need to mention them. Conversely, in cosmological theory and speculation, as is the concern of the Ṛgvedic code, information about the planets should show up. With this background we take up the question of planetary astronomy. We will provide evidence in support of the view that period information on the planets was known. We will also sketch how the hymn numbers were chosen.

The references to the five planets in the Vedic literature are commonly expressed in the mention of the thirty-four lights (RV 10.55.3) which are the twenty-seven nakṣatras, the sun, the moon, and the five planets. The five planets are apparently mentioned in RV 1.105.10 and Bṛhaspati (Jupiter) is referred in RV 4.50.4 and Vena (Venus) is mentioned in RV 10.123. It is possible that Venus was known as Śukra (RV 3.32.2), as suggested by ŚB 4.2.1. The identification of Vena with Venus is supported by several independent references. The reference to the sapta sūryāḥ (seven suns), as in RV 1.105.5 and RV 8.72.16, seems to indicate the sun, the moon, and the five planets.

If we accept that the planets were carefully observed then it becomes plausible that their periods were known. But it is possible that the knowledge was obtained only at the time of the arrangement of the hymns into the Ṛgveda. If this were true then the credit for this knowledge should go to the arranger Kṛṣṇa Dvaipāyaṇa Vyāsa.

It has been suggested that the correct interpretation of the solar eclipse described in RV 5.40.5-9 is that Atri knew when the eclipse will be over. The fifth book is by Atri and his family and tradition considers him to be one of the teachers of astronomy. Tradition also considers Vyāsa as a great teacher of astronomy. It is likely that he was one in a long chain of astronomer-seers.

If the periods of the five planets were known, it is possible that they are contained in the Ṛgvedic astronomical code. The sidereal and the synodic periods are given in days in Table 6.3.

Table 6.3: Sidereal and Synodic Periods in Days

| Planet | Sidereal Period | Synodic Period |
|---|---|---|
| Mercury | 87.97 | 115.88 |
| Venus | 224.70 | 583.92 |
| Mars | 686.98 | 779.94 |
| Jupiter | 4332.59 | 398.88 |
| Saturn | 10759.20 | 378.09 |

We consider the sidereal periods first. We expect that the three sidereal periods less than 1017 are amongst the combinations. There is evidence that the approximation of 87 was used for the sidereal period of Mercury for this planet is difficult to observe.

It appears that the synodic period of Mercury was taken to be one third of the year of 360 days and that the sidereal period of 87 is one third of the sky number 261 played some role in this choice, which is an example of the case where observations are modified to fit a theory.

Although numerical considerations may have compelled the use of 87 as the period of Mercury we believe that this period was not computed to the same accuracy as others. The sidereal periods can be factored into the components given in Table 6.4.

Table 6.4: Sidereal Periods Factored

| |
|---|
| $87 = 87 \times 1$ (Mercury) |
| $225 = 58 + 75 + 92 = 75 \times 3$ (Venus) |
| $687 = 191 \times 3 + 114 \approx 43 \times 16$ (Mars) |
| $4332 \approx 62 \times 70 \approx 58 \times 75$ (Jupiter) |
| $10760 \approx 104 \times 104 \approx 92 \times 117$ (Saturn) |

Factors from each of these equations show up in the Book hymn numbers. It may be supposed that these factors were the starting points in the construction of the code. Similarly, factors of the year were used in the choice of the number of bricks in different layers of the agnicayana altar. It is likely that the specific factors of the sidereal periods were chosen so that other astronomically significant numbers would be obtained. This is why the sidereal periods also show up as number of hymns in Book combinations.

Now consider the synodic periods. One sees that for Mercury, Venus, Mars, Jupiter, and Saturn 23, 5, 8, 9, and 29 synodic periods are completed in nearly 10, 8, 17, 10, and 30 years, respectively, requiring a new cycle to begin every 2040 years. A different fit is provided by the synodic periods 3, 72, 15, 120, and 30 which are completed in 3, 115, 32, 130, and 31 years. The least common multiple of the synodic periods is now 1080. The centrality of the number 108 in the altar construction of agnicayana indicates that the second set was used. This again indicates that the period of Mercury was not represented with the same accuracy as of the other planets.

The 1023 combinations of the 10 hymn numbers map into 461 different numbers. While this is a large set, the fact that all the synodic periods, with the assumption that the period of Mercury is represented by 120 days, show up in this set within an error of one day is significant. A non-unique set is provided in Table 6.5.

Table 6.5: Synodic Periods in Days by Books

| |
|---|
| Books [3+4] = 120 (Mercury) |
| Books [1+5+9+10] = 583 (Venus) |
| Books [1+5+7+8+9+10] = 779 (Mars) |
| Books [2+3+5+8+9] = 398 (Jupiter) |
| Books [2+4+5+6+9] = 377 (Saturn) |

Apart from these numbers we also obtain 118, 780 and 379 that provide even better approximations.

The fame of the Ṛgvedic book arrangement partly rested on the fact that it also gives the synodic periods in tithis especially since the use of the tithi (the lunar year divided into 360 parts) was commonly used in altar ritual. But how can we be certain that the usage of tithi during the Ṛgvedic phase was similar to its later usage? The Vedāṅga Jyotiṣa takes a yuga of five years to be equal to 1,830 sidereal days or 62 synodic months or 1,860 tithis. Much later, Varāhamihira takes the yuga to contain 1,830 civil days rather than sidereal days. It is clear that the measure of tithi was not determined by precise measurement and it was used in relation with the year or several years to check the sun and the moon against the stars.

Paralleling the representation of the tropical year by 371 or 372 tithis, when the correct value is close to 371.05 tithis, one would expect that the tithis for each synodic period would be rounded to the next higher number if the fractional part is significant. The synodic periods in tithis are 117.72, 593.20, 792.34, 405.22, and 384.10 respectively. For Saturn one would expect both 384 and 385 to be used. In other words, the periods would be taken to be 118, 594, 793, 406 for Mercury, Venus, Mars, and Jupiter and 384 or 385 for Saturn. All of these numbers also show up in the combinations.

## Probabilistic Analysis

Ad mentioned in the previous section, there are several independent arguments that suggest that the planet period information went into the definition of the code. These include the fact that the hymn totals of the books are the factors of the sidereal periods of the planets and that the sums of these numbers yield the sidereal periods. Although the combinations are very many, it is important to note that the combinations of very few terms yield astronomically significant numbers. One would expect that the Ṛgvedic astronomers did not attempt all the combinations but checked if the numbers of significance did show up. The fact that this happened was proof to these astronomers that the code expressed significant relationships (*bandhu*) between diverse phenomena.

Support for this argument is obtained by considering all the combinations of the numbers of hymns in the Aṣṭaka division of the Ṛgveda. The number of unique combinations generated equals 179. These do not include any of the sidereal periods and only two of the five synodic periods in tithis, and the significant sun-step number of 339 is also not generated. In other words these combinations contain very few of the astronomically significant numbers that the combinations of the Book hymn numbers have yielded.

From a probabilistic point of view it is to be expected that the 179 Aṣṭaka numbers out of 1017 would give two fits out of randomly chosen ten numbers which is what we obtain. On the other hand the 451 Book (Maṇḍala) numbers should give correct choices only in half the cases. But we get the hymn numbers that are factors of the sidereal periods, and we get combinations for the three sidereal periods, five synodic periods in days as well as the five synodic periods in tithis.

Let the probability of picking a correct number be $p$. Considering a random model of choice, in a sample of $n$ the expected number of correct picks is $\mu = np$ and the variance is $\sigma^2 = np(1-p)$. A sample of twenty-three numbers, as in our case, implies that $\mu = 11$ and $\sigma = 2.39$. And that all the twenty three numbers are correct implies that we are five standard deviations away from the mean. The probability of that happening is $2.87 \times 10^{-7}$.

One might argue that only ten of the twenty three numbers must be considered to be primary and that the comparison should be based on the sample size being equal to ten. In this case $\mu = 4.5$ and $\sigma = 1.58$ so that the probability of obtaining ten significant random numbers in a sample of ten is $2.33 \times 10^{-4}$. These probabilities are so small that the claim that the Book numbers were deliberately chosen may be taken to be confirmed.

Corroboration for the conclusion that the Vedic world knew the planetary periods may be sought in the artifacts and astronomical designs from the Harappan ruins, since that civilization is coeval with the Vedic. It also becomes reasonable to reexamine the Vedic literature for further knowledge about the planet motions.[3]

## The Planet Names

The list below brings together some of the names of the planets, together with the ascribed colours, used in a variety of places in the Vedic and the later Purāṇic literature.

MERCURY. Budha, Saumya, Rauhiṇeya, Tuṅga (*yellow*)

VENUS. Vena, Uśanas, Śukra, Kavi, Bhṛgu (*white* )

MARS. Aṅgāraka, Bhūmija, Bhauma, Maṅgala, Kumāra, Skanda, Lohitāṅga, (*red* )

JUPITER. Bṛhaspati, Guru, Āṅgiras (*yellow*)

SATURN. Śanaiścara, Sauri, Manda, Paṅgu, Pātaṅgi (*black* )

Mercury is viewed as the son of the moon by Tārā, the wife of Jupiter, or the nakṣatra Rohiṇi (Aldebaran), Venus as the son of Bhṛgu and the priest of the demons, Mars as the son of the earth or Śiva, Jupiter as the son of Aṅgiras and the priest of the gods, and Saturn is seen as being born to Revatī and Balarāma or to Chāyā and the sun. Saturn is described as the lord of the planets, lord of seven lights or satellites, and the slow-goer. Since the Indian calendar was reckoned according to the constellation at the vernal equinox, one may assume the name "son of Aldebaran" means that Mercury was first noted during the era of 3400-2210 BCE when the vernal equinox was in the Pleiades.

The Jaiminigṛhyasūtra (2.9) gives the following equation between the planets and the Vedic gods: the sun is Śiva; the moon is Umā (Śiva's wife); Mars is Skanda, the son of Śiva; Mercury is Viṣṇu; Jupiter is Brahman (symbolizing the entire universe); Venus is Indra; and Saturn is Yama, the "dual" god (death). The colors assigned to the planets are from the same source.

One may speculate that the equation of Saturn and Yama arises out of the fact that the synodic period of Saturn is the "dual" to the lunar year; 378 days of Saturn and 354 days of the lunar year with the center at the 366-day solar year.

## The Identity of Mercury and Viṣṇu

Mercury's identification with the god Viṣṇu, an important figure in the Ṛgveda, is of particular significance. Viṣṇu is the younger brother of Indra in the Ṛgvedic era; and Indra is sometimes identified with the sun. The most essential feature of Viṣṇu are his three steps by which he measures out the universe (e.g. RV 1.154). Two of these steps are visible to men, but the third or highest step is beyond the flight of birds or mortals (RV 1.155, 7.99). In later mythology it is explained that Viṣṇu did this remarkable thing in the incarnation as Vāmana, the pygmy. This agrees with the identification as the small Mercury.

What do these steps mean? According to late tradition, Viṣṇu is a solar deity and these three steps represent the sunrise, the highest ascent, and the sunset. Another equally old interpretation is that the three steps represent the course of the sun through the three divisions of the universe: heavens, earth, and the netherworld.[4]

But both of these interpretations appear unsatisfactory, for neither of them squares with the special significance attached to the third step. Nor does they explain the putative identity of Mercury and Viṣṇu.

A new explanation emerges when we consider altar ritual. The universe is represented in time symbolically by the number 360. The year is divided into two halves: 183 days for the northern course of the sun and 183 days for the southern course of the sun. The symbolic year of 360 days is divided further into three parts: 261 for sky, 78 for space, and 21 for earth.

Since Viṣṇu is Mercury it is natural to suppose that the three steps of Viṣṇu are nothing but the three revolutions of Mercury in a cycle of 261 sky days. With this supposition the period of Mercury is 87 days. This is precisely the value indicated by the Ṛgvedic astronomical code. Furthermore, the synodic period of Mercury is taken to be 120 days in the Ṛgvedic code and three such periods equal the 360 days. In tithis, this equals 118 and three times that is 354, which is the lunar year count. It appears that this dual relationship led to the great importance being given to the myth of the three steps of Viṣṇu.

The name of Budha for Mercury appears in the Pañcaviṃśa Brāhmaṇa (PB), which is post-1900 BCE since it has an account of a journey to the source of Sarasvatī from the place where it is lost in the desert (PB 25.10). PB 24.18 speaks of Budha in connection with a 61 day rite. Three such rites imply a total of 183 days which equals the days exclusively devoted to the heavens. This appears to be the analog, in the field of ritual, of the three steps of Viṣṇu covering the heavens.

We have presented evidence showing that the understanding of the motions of the planets arose at some time during the unfolding of the Ṛgvedic period. For example, Venus is described in early Vedic mythology in terms of the twin Aśvins, the morning and evening stars just as Homer later describes it as the pair Hesperus and Phosphorus. This commonality indicates early Indo-European basis to this myth.

The main characters in the planetary myths are Jupiter and Venus, as is to be expected for the two brightest planets. Venus, in its earlier incarnation as the Aśvin twins, was seen as born to the sun. Mercury as Viṣṇu is Upendra, the younger brother of the Indra, here a personification of the sun. But once Mercury fitted into the planetary scheme, its association with Viṣṇu was forgotten. Later accounts describe the planets in relation to each other. Our arguments showing that the period of Mercury was obtained in the third millennium BCE imply that as the determination of the period of Mercury is the hardest amongst the classical planets, the periods of the other planets had already been obtained.

The motion of the planets needed to be defined in relation to fixed stars and the constellations. Apart from the naklṣatras and their stars (constellations on the ecliptic that will be discussed further in a later chapter), the other stars described in the Sūrya Siddhānta include the Saptarṣi (Seven Sages, Ursa Major), Agastya (Canopus), Mṛgavyādha (Sirius), Agni, Brahmahṛdaya (Capella), Prajāpati, Apāmvatsa, and Āpas. As divine figures, these names are an integral part of the Vedic literature. The polar longitude and latitude of these stars are given in the Sūrya Siddhānta. The nakṣatra names are rich in their description and they provide valuable information on their role in specific rites that has implications for the chronology of the age. This issue will also be discussed further.

The literature that followed the Ṛgvedic age was at first concerned with the ritual related to the earlier astronomy of the Vedic age. Once the planetary system fell into place, the gods became supernumeraries and the focus shifted to their duals that inhabit the inner universe. Thus, by the time of the Śatapatha Brāhmaṇa, the original stars of the Ursa Major were identified with the cognitive centers in the brain as in ŚB 8.1 or in more detail in the Bṛhadāraṇyaka Upaniṣad (2.2.4). Evidently this could have only occurred much after the explication of the planetary motions that took place in the third millennium BCE.

# 7. *The Code in the Atharvaveda*

## On Canonicity

Is the code in the organization of the Ṛgveda present in other texts and does its occurrence represent canonicity in some sense? We would also like to know if there are varieties of this code, and what class of texts, written in what period, exhibit such a code. In this chapter we consider the Atharvaveda and the Bhagavadgītā and show that the code numbers are reflected in their organization.

The Āraṇyakas represent a watershed in Vedic history, and it appears that the material that followed them was generally not informed by this code. The code is not mentioned in the Vedic indexes. The Buddhist and the Jain philosophers were not aware of the astronomical basis of the fire altars either. The code explains several numerical aspects of the Vedic ritual which are left unexplained in the Sūtra manuals and, therefore, one may take it to predate these later texts. One may assume that if a text is organized according to the numbers of the code then that constitutes evidence supporting a date that is pre-Buddhistic. Conversely, it is possible that the code continued to be known but only to the initiated.

The Atharvaveda was originally called Atharvāṅgirasaḥ, or the Veda of the Atharvan and the Aṅgiras. The arrangement of the Atharvaveda is by tradition supposed to have occurred at about the same time as the other Vedas. But the other Vedas were substantially complete much before the time of Vyāsa (as they borrow much from the Ṛgveda) whereas the Atharvaveda borrows from other sources as well, especially in its late books. In fact one might propose that the various recensions of the Vedic books that arose soon after Vyāsa reflected different modifications to the astronomical constants inherent in the original arrangements. When the astronomical basis was forgotten there was no incentive to make additional changes.

The Bhagavadgītā is in the beginning of the sixth book of the Mahābhārata. While the epic has some very late portions, its core goes back to the times of the Bhārata War. It is likely that Kṛṣṇa, the son of Devakī, whom we come across in Chāndogya Upaniṣad, is the hero of the Bhagavadgītā. Vaiśampāyana, Vyāsa's pupil, enlarged the account of the Bhārata War. It was further enlarged by Ugraśravas, the son of Lomaharṣana (sometimes called Romaharṣana). Oral transmission by bards during succeeding centuries caused new material to be added to it.

The Mahābhārata tradition itself claims that the text was originally 8,800 verses by Kṛṣṇa Dvaipāyana Vyāsa when it was called the Jaya. Later, it was enlarged to 24,000 verses and it came to be called the Bhārata. It was transmitted by Vyāsa to Vaiśampāyana and finally recited by Ugraśravas as the Mahābhārata of the 100,000 verses; the two latter sages appear thus to be responsible for the bulk of its enlargements.

The Upaniṣads speak of texts called Itihāsa-Purāṇa and although the Mahābhārata is called Itihāsa, there is no certainty that this was the only such Itihāsa text that has ever existed. Some believe that there was an old kernel of the story going back to the Mahābhārata War, but the expansion of the text into the three phases of the Jaya, the Bhārata, and the Mahābhārata took place only after 400 BCE.

Pāṇini speaks of the Bhārata and the Mahābhārata in one of his sutras (6.2.38). This means that the epic was substantially complete by 500 BCE, although it may have undergone further interpolations in subsequent centuries. The Mahābhārata does not mention Buddhism, although it has much material on religion.

The Bhagavadgītā has been subjected to considerable analysis to determine its core text, but such studies have failed to find different layers and the text displays remarkable coherence.[1]The Kashmir recension, which is a bit longer than the standard version, appears to be an enlargement.[2]

Given the flawed and confused basis on which the chronology of the earliest Sanskrit texts is based, it is hard to date the Bhagavadgītā. It is quite likely that this book is centuries older than is commonly accepted. By speaking simultaneously at three levels: the cosmic, the terrestrial, and the spiritual, the author shows that he was well versed in the tripartite Vedic system of knowledge. At the same time, the book criticizes meaningless Vedic ritual suggesting the author was aware that the original astronomical basis of this ritual had ceased to be valid. The book's focus is the essence of

Vedic knowledge, which is why it is correctly termed an Upaniṣad.

Nevertheless the discovery that the Bhagavadgītā reflects the Ṛgvedic code comes as a surprise. Actually, the three numbers 21, 78, 261 remained well-known and we encounter them in other texts as well.

## The Organization of the Atharvaveda

Although the Śaunakīya recension of the Atharvaveda consists of 20 books (kāṅḍa) in 730 or 731 hymns (sūktas),[3] we show that the core of the Atharvaveda consists of 565 hymns. The books are often represented as 19 main books and an appendix called the Kuntāpa-khila that is a part of the Book 20 that consists of 133 additional hymns. This last book is almost entirely of hymns taken from the Ṛgveda. In addition to this book approximately one seventh of the rest of the material in the Atharvaveda is also taken from the Ṛgveda. Half of this material is found in Book 10 and most of the remaining material is found in Books 1 and 8 of the Ṛgveda. As we have shown in Chapter 5, this repetition must have been caused by an attempt to reach a certain size.

These main books fall into four divisions. The first division consists of Books 1 through 7 that have hymns that vary from 1 to 18 verses. The second division consists of Books 8 through 12 where the hymns have verses that vary from 21 to 73. The third division consists of Books 13 through 18 which are characterized by a unity of subjects. These books are called the Rohita, Wedding, Vrātya, Paritta, Sun, and Funeral books, respectively. The hymns here vary from lengths of 26 to 91 verses. The hymns of Book 19 have lengths less than 20 verses, with two exceptions of 19.22 and 19.23 where the lengths are 21 and 30 verses. The other hymns of Book 19 fall into the same category as books of the first division. The Kuntāpa khila of Book 20 consists of 10 hymns of 150 verses.

The various ways the hymns might be represented results in different counts for the total number of verses. In Chapter 5 we stated the tradition where the verses in all the twenty books of the Atharvaveda total 5,977. When only the first nineteen books are counted we have 5,076 verses[4]. Together with the 150 verses of the Kuntāpa khila, the core Atharvaveda consists of 5,226 verses which is $78 \times 67$. The fact that this number is divisible by the altar number 78 is significant. The number of hymns in the Books 15 and 16 is taken as two each as stated by the Anukramaṇī tradition.[5]

Table 7.1: Books of the Atharvaveda

| Books | Hymns | Verses |
|---|---|---|
| 1 | 35 | 153 |
| 2 | 36 | 207 |
| 3 | 31 | 230 |
| 4 | 40 | 324 |
| 5 | 31 | 376 |
| 6 | 142 | 454 |
| 7 | 118 | 286 |
| 8 | 10 | 283 |
| 9 | 10 | 313 |
| 10 | 10 | 350 |
| 11 | 10 | 367 |
| 12 | 5 | 304 |
| 13 | 4 | 188 |
| 14 | 2 | 139 |
| 15 | 2 | 220 |
| 16 | 2 | 103 |
| 17 | 1 | 30 |
| 18 | 4 | 283 |
| 19 | 72 | 456 |
| Totals | 565 | 5,076 |

The eighteen paryāyas of Book 15 fall into two groups of 7 and 18, and in Book 16 the grouping is in terms of 4 and 5 paryāyas. Internal support for this comes from AV 19.23.25 where there is a reference to the two Vrātyas of Book 15. The organization of this core of Atharvaveda is summarized in Table 7.1.

Note that the total number of hymns is 565 which is $113 \times 5$, and that 113 is one-third the number of sun-steps in the day. As to the significance of considering a number that is exactly five ninths the number of hymns in the Ṛgveda we cannot tell at this time. Nevertheless, this establishes that the organization of the Ṛgveda and the Atharvaveda was either by the same person, or by persons who were aware of the astronomical code.

It is interesting to note the various kinds of symmetries amongst the books in terms of the hymn totals. One way to represent these is Table 7.2.

Table 7.2: Book symmetries

| |
|---|
| Book[20; 143] |
| Books[8 through 19;142] |
| Book[7;118] |
| Book[6;142] |
| Book[3;31], Book[4;40], Book[5;31] |
| Book[1;35], Book[2;36] |

A characteristic of these symmetries is the deficit of one that we see comparing Books 1 and 2 or Books 6, and sum of Books 8 through 19, and Book 20.

As in the Ṛgvedic books, one may also view the Atharvaveda books as a five-layered altar. One arrangement designed to parallel the book-altar of the Ṛgveda, is shown in Table 7.3.

Table 7.3: Atharvaveda books as an altar

| | |
|---|---|
| Book[19] | Books[13 through 18] |
| Book[7] | Books[8 through 12] |
| Book[5] | Book[6] |
| Book[3] | Book[4] |
| Book[2] | Book[1] |

The hymn numbers in such an altar are shown explicitly in Table 7.4.

Table 7.4: The hymn numbers in the altar

| | |
|---|---|
| 72 | 15 |
| 118 | 45 |
| 31 | 142 |
| 31 | 40 |
| 36 | 35 |

If we add up the numbers in the first column we obtain 288 whereas the sum of the numbers in the second column is 277. If the 10 Kuntāpa hymns were meant to bring the second column upto 287, then we are left with the characteristic deficit of one.

Whitney divided Book 15 into 18 hymns and Book 16 into 9 hymns. Together with the 143 hymns of the Book 20 (that include the ten Kuntāpa hymns) we get a total of 731 hymns by this reckoning. But we have seen that Whitney's division goes against the Anukramaṇīs as well as the inner logic of the text.

To conclude, the core Atharvaveda should be taken to be 565 hymns. Together with the hymns of Book 20, we get a total of 708 hymns. Our conclusion that Book 19 belongs to the core text implies that the list of 28 nakṣatras given in 19.7 must date to at least the close of the Vedic age.

The twenty books may be arranged in an interesting book-altar when Books 1 and 2 are combined. As shown by Table 7.5 this provides a certain symmetry in the bottom two layers.

Table 7.5: Book altar for all the twenty books

| | |
|---|---|
| 143 | 72 |
| 45 | 15 |
| 142 | 118 |
| 40 | 31 |
| 31 | 71 |

Furthermore, there is an increase of 102 in going from the second to the third layer in the first column; correspondingly, this equals the sum of the bottom two numbers in the second column. The increase from the second to the third place in the second column is 87; this equals the sum of the top two numbers in the same column. We do not know the significance of these numbers at this time.

## The Structure of the Bhagavadgītā

The text of the Bhagavadgītā has traditionally been examined from the point of view of the subject matter. Scholars have sought to separate the Vedāntic portions from those relating to sāṅkhya-yoga and bhakti-yoga. But it was found that these strands are woven together in an astonishingly unified text.

Here we view the Bhagavadgītā from the point of view of the four participants of its dialogue: Dhṛtarāṣṭra, Sañjaya, Arjuna, and Kṛṣṇa. Of these Arjuna and Kṛṣṇa are the main characters and Dhṛtarāṣṭra and Sañjaya are the observers of the dialogue. A deliberate design of the Bhagavadgītā might then reflect these numbers in terms of the verses spoken by each. The number of verses spoken by each is as follows:

Table 7.6: Chapters and verses

| Chapter | Dhṛtarāṣṭra | Sañjaya | Arjuna | Kṛṣṇa | Total |
|---|---|---|---|---|---|
| 1 | 1 | 24.5 | 21 | 0.5 | 47 |
| 2 | | 2.5 | 6.5 | 63 | 72 |
| 3 | | | 3 | 40 | 43 |
| 4 | | | 1 | 41 | 42 |
| 5 | | | 1 | 28 | 29 |
| 6 | | | 5 | 42 | 47 |
| 7 | | | | 30 | 30 |
| 8 | | | 2 | 26 | 28 |
| 9 | | | | 34 | 34 |
| 10 | | | 7 | 35 | 42 |
| 11 | | 8 | 33 | 14 | 55 |
| 12 | | | 1 | 19 | 20 |
| 13 | | | | 34 | 34 |
| 14 | | | 1 | 26 | 27 |
| 15 | | | | 20 | 20 |
| 16 | | | | 24 | 24 |
| 17 | | | 1 | 27 | 28 |
| 18 | | 5 | 2 | 71 | 78 |
| Totals | 1 | 40 | 84.5 | 574.5 | 700 |

Grand Total= 700 verses.

On two occasions, half-verses are ascribed to Arjuna and Kṛṣṇa when they are quoted by Sañjaya as happens in Chapters 1 and 2. The specific examples are 1.25 where Sañjaya quotes Kṛṣṇa for half a verse and in 2.9 where he quotes Arjuna.

We note that the total number of verses spoken by Arjuna and Kṛṣṇa is 659. As a fraction of the total it equals $659/700 = 94.14\%$. On the other hand the fraction $339/360 = 94.16\%$.

With the constraint of 700 as the total number of verses this is as close as one can get to the basic Ṛgvedic ratio of 339/360. One might wonder if this is a coincidence, but laws of probability would rule against that.

Another reference to an astronomical number is the sum of the first 9 chapters which equals 372 verses or the number of tithis (lunar days) in a year.

**Vyāsa's Signature**

Tradition ascribes the arrangement of the Vedas as well as the authorship of the Bhagavadgītā to Kṛṣṇa Dvaipāyana Vyāsa. The ratio of 339/360 is a commonality between the two. Perhaps one can consider it as a signature by Vyāsa or by one that knew of this tradition. Another commonality amongst the books ascribed to Vyāsa is a division into eighteen chapters.

Why 700 verses were chosen for the book is not clear. But this number is very close to the Vedic number 78, the number for space, because $78 \times 9 = 702$. If 702 was the original number then 2 verses are now lost. It is possible that the book started out with 702 verses to be consistent with the requirement that the total be a multiple of 78. (For example the total number of verses in all the Vedas is $20358 = 261 \times 78$.) However, the imposition of the further requirement of the ratio 339/360 then called for a pruning of two verses.

Another possibility is that $700 = 339 \times 2 + 21 + 1$. Here 21 is the earth and 1 is representative of the transcending unity. If the second explanation is right then the Bhagavadgītā has retained the form in which it was conceived.

# 8. *Distance to the Sun*

## Planetary System Models

We consider further astronomical ideas of the Vedic period. We are also interested in determining if there is a relationship of these ideas to those elsewhere in the world.

According to the history of ancient mathematical astronomy by Neugebauer,[1] Ptolemy in second century CE, using a method developed by Hipparchus, came to the conclusion that the sun is about 600 earth diameters distant from the earth. This estimate held sway during the Middle Ages until the time of Copernicus and Brahe. Kepler argued for a distance three times this value but it was not before the end of the seventeenth century that it was found that Ptolemy's estimate was wrong by a factor of about seventeen.

In this chapter we sketch the early history of the knowledge of the distance of the sun from the Indian sources with which Neugebauer was not familiar. We have seen that the knowledge of the constellations and the planet periods can be traced at least to the third millennium BCE and the motions of the sun and the moon to at least the second millennium BCE. Such knowledge must have emerged out of a theory about the size of the universe, indicating that theories on the relative dimensions of the solar system are old. How did the understanding of the relative distances of the sun and the moon emerge? And how did it evolve?

The earliest Indian evidence comes from the Ṛgveda where there is assertion that the universe is infinite in extent (e.g. RV 1.52.13). Numbers as large as $10^{12}$ are described in other Vedic texts. Ṛgveda 1.35.7-9 suggests that the sun is at the center of the universe for the rays of the sun range from the earth to the heavens.

More practical evidence is found in the Brāhmaṇas. For example, Śatapatha Brāhmaṇa 6.1.10 to 6.2.4 gives a brief account of the creation of the universe in which several elements related to the physical and the psychological worlds are intertwined. Within this account the description of the physical world is quite clear. It begins with the image of a cosmic egg, whose shell is the earth (6.1.11). From another cosmic egg arises the sun and the shell of this second egg is the sky (6.2.3). The point of this story is to suggest that the universe was perceived in the shape of an egg with the earth as the center and the sun going around it underneath the heavens.

It is possible that the view of the infinite universe was reconciled to that of one cosmic egg by considering the latter to refer to our solar system. In the Purāṇic accounts, the stars are seen to lie at varying distances with the polestar as the furthest. Beyond the star system of this world are other worlds, with their own Indras.

It is also possible that other ideas, not compatible with each other, had currency. The idea of many worlds with their own Indras indicates an infinite physical universe. The notion of an egg-shaped world within this universe could be seen as one of many island universes. These conceptions could also be viewed from the perspective of recursion, a central Vedic theme, in which structures repeat themselves across space, time, and scale.

The Atharvaveda (10.7) presents an image of the frame of the universe as a cosmic pillar (*skambha*). In this the earth is the base (10.7.32), the space the middle parts, and the heavens the head. The sun, in particular, is compared to the eye (10.7.33). But there is no evidence that this analogy is to be taken in a literal fashion. One can be certain that in the Vedic period, the sun was taken to be less distant than the heavens.

It was a common supposition in the ancient world to take the motions of all the heavenly bodies to be uniform. For example, such a system of circular motions is considered in the Vedāṅga Jyotiṣa.

The relative distance of a body from the earth was, therefore, determined by its period. This set up the following arrangement for the luminaries:

*Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn*

Since the sun was halfway in this arrangement, it is reasonable to assume that the distance to the sun was taken to be half of the distance to the heavens. The notion of the halfway distance must date from a period when the actual periods were not precisely known or when all the implications of the period values for the size of the universe were not understood. It is not clear that a purely geocentric model was visualized.

It appears that the planets were taken to go around the sun which, in turn, went around the earth. One evidence is the order of the planets in the days of the week where one sees an interleaving of the planets based on the distance from the sun and the earth, respectively; this suggests that two points of focus, the earth and the sun, were used. Further evidence comes from the fact that the planet periods are given with respect to the sun in the later work of Āryabhaṭa. The purely geocentric model may have been a later innovation.

## The Pañcaviṃśa Brāhmaṇa (PB)

The *Pañcaviṃśa Brāhmaṇa (PB)* (The Brāhmaṇa of Twenty-five Chapters) 25.10 has an account of a journey to the source of the river Sarasvatī from the point it gets lost in the desert. If the drying up of Sarasvatī took place in around 1900 BCE, the text is later than that epoch. Internal astronomical evidence of the Brāhmaṇas indicates that they date from different times in the second millennium BCE. Further evidence for this dating comes from the fact that the Brāhmaṇas describe rites where the interval from the winter solstice to the summer solstice is exactly 180 days, which was true for the second millennium BCE.

*PB* is a book that lists rites of varying durations and the astronomy given in it is incidental to the description of the rites. The rites themselves appear to have an astronomical intent as given by their durations: 1 through 40 days (excepting 12), 49, 61, 100, and 1000 days; 1, 3, 12, 36, 100, and 1000 years. The rites provide a plan for marking different portions of the year and also suggest longer periods of unknown meaning.

In *PB* 16.8.6 we have a statement about the distance of the sun from the earth:

> *yāvad vai sahasraṃ gāva uttarādharā ity āhus tāvad asmāt lokāt svargo lokaḥ*
>
> The world of heaven is as far removed from this world, they say, as a thousand earths stacked one above the other.

Caland[2] translates this as "as a thousand cows standing the one above the other." The Sanskrit word *gauḥ* has several meanings including the primary meanings of "earth" and "cow" but considering the context the translation by Caland is definitely wrong.

Looking at the earliest Indian book on etymology, Yāska's *Nirukta*. the meaning of *gauḥ*, of which *gāvaḥ* is plural, is given as: "[It] is a synonym of 'earth' because it is extended very far, or because people go over it .... It is also a synonym of an animal (cow) from the same root." (*Nirukta* 2.5)[3]

Now the question arises where was the sun conceived to be in relation to the heavens. The Śatapatha calls the sun the lotus of the heavens in ŚB 4.1.5.17.

Let $R_s$ represent the distance between the earth and the sun, $R_m$ be the distance between the earth and the moon, $d_s$ be the diameter of the sun, $d_m$ be the diameter of the moon, and $d_e$ be the diameter of the earth.

According to *PB*, $R_s < 1000\ d_e$, and we take that

$$R_s \approx 500 d_e$$

Earlier we have discussed the evidence that the ancients were aware of the relationship:

$$R_s \approx 108 d_s$$

and

$$R_m \approx 108 d_m$$

This could have been easily determined by taking a pole and removing it to a distance 108 times its height to confirm that its angular size was equal to that of the sun or the moon. This also implies that the heavens were taken to be 216 solar diameters from the earth.

Considering a uniform speed of the sun and the moon and noting that the sun completes a circuit in 365.24 days and the moon 12 circuits in 354.37 days, we find that

$$R_m \approx \frac{354.37 \times 500}{365.24 \times 12} d_e$$

or

$$R_m \approx 40 d_e$$

Also we have a relationship on relative sizes because

$$R_s \approx 108 d_s \approx 500 d_e$$

This means that $d_s \approx 4.63 \times d_e$.

A theory on the actual diameters of the sun, the moon, and the earth indicates a knowledge of eclipses. The much older Ṛgveda (5.40) speaks of a prediction of the duration of a solar eclipse, so relative fixing of the diameters of the earth, the moon, and the sun should not come as a surprise.

Also note that the long periods of Jupiter and Saturn require that the sun be much closer to the earth than the midpoint to the heavens, or push the distance of the heavens beyond the $1000d_e$ of *PB* and perhaps also make the distance of the sun somewhat less than $500d_e$. We do see these different modifications in the models from later periods.

PB 25.10.16 also states the duration from the earth to heaven is as long as a journey of 44 days and this is equated, symbolically, to the travel, on horseback, between the point where Sarasvatī is lost in the desert and its source in the mountains. But we are not certain of the astronomical significance of this duration of 44 days.

The distances to the planets and the size of the universe as given in the Sūrya Siddhānta. The Sūrya Siddhānta 12.84 says: "Any orbit, multiplied by the earth's diameter and divided by the earth's circumference, gives the diameter of that orbit; and this, being diminished by the earth's diameter and halved, gives the distance of the planet." The next verses give the distances as follows:

Table 8.1: Distances to planets and stars in yojanas

| | |
|---|---:|
| Moon | 324,000 |
| Mercury (conjunction) | 1,043,209 |
| Venus (conjunction) | 2,664,637 |
| Sun | 4,331,500 |
| Mars | 8,146,909 |
| Jupiter | 51,375,764 |
| Saturn | 127,668,255 |
| Asterisms | 259,890,012 |
| Brahmāṇḍa | 18,712,080,864,000,000 |

The rays of the sun are supposed to reach the far edge of the Brahmāṇḍa. One would presume that other island Brahmāṇḍas are taken to exist beyond this edge.

## Planet Sizes in Āryabhaṭa's Astronomy

By way of comparison, we provide the values for various sizes and distances from the *Āryabhaṭīya (AAr)* of Āryabhaṭa (c. 500 CE). Āryabhaṭa explains the motion of the stars as a result of the rotation of the earth and the motions of the planets are explained in terms of epicycles that, in contrast to the Greek theory, expand and contract rhythmically. Furthermore, he gives the planetary periods relative to the sun which *appears* to be based on an "underlying theory in which the earth (and the planets) orbits the sun."

The basic measure in this text is to take 8,000 *nṛ* to be equal to a yojana, where a *nṛ* is the height of a man; this makes a yojana approximately 7.5 miles. *AAr* 1.7 gives the following measures for the diameters:

Table 10.2: Planetary diameters in yojanas

| | |
|---|---|
| Earth ($d_e$) | 1,050.00 |
| Sun ($d_s$) | 4,410.00 |
| Moon ($d_m$) | 315.00 |
| Mars | 12.60 |
| Mercury | 21.00 |
| Jupiter | 31.50 |
| Venus | 63.00 |
| Saturn | 15.75 |

Furthermore, *AAr* 1.6 gives the distance of the sun, $R_s$, to be 459,585 yojanas, and that of the moon, $R_m$, as 34,377 yojanas.

It follows then that in *AAr*,

$$R_s = 437.7 d_e$$

and

$$R_m = 32.74 d_e$$

Also,

$$R_s \approx 104.21 d_s$$

and

$$R_m \approx 109.13 d_m$$

Comparing the earlier figures of the *PB* era it is clear that the $R_m$ had to be reduced to account for the extra time spent in the epicyclic motions of *AAr*.

## Indian and Greek Models

We first note that the idea that the sun is roughly 500 or so earth diameters away from us is much more ancient that Ptolemy. So Neugebauer was wrong on two counts: first, he did not know of any Indian connections although he admitted that the "study of Hindu astronomy is still at its beginning;" second, he did not recognize that the tradition regarding the distance of the sun might be much older in Greece itself. This greater antiquity is in accordance with the ideas of van der Waerden,[4] who ascribes a primitive epicycle theory to the Pythagoreans. But it is more likely that the epicycle theory is itself much older than the Pythagoreans and it is from this earlier source that the later Greek and Indian modifications to this theory emerged which explains why Greek and Indian models differ in crucial details.

It should also be noted that Ptolemy's Almagest is a 12th century Arabic book that is likely to include much information of the first millennium astronomy and its original 2nd century form cannot be established with certainty.

Did the idea that $R_s \approx 500d_e$ originate at about the time of *PB*, that is from the second millennium BCE, or is it older? Since this notion is in conflict with the data on the periods of the outer planets, it should predate that knowledge. If it is accepted that the planet periods were known by the end of the third millennium BCE, then this knowledge must be assigned an even earlier epoch. Its appearance in *PB*, a book dealing primarily with ritual, must be explained as a remembrance of an old idea. We do know that *PB* repeats, almost verbatim, the Ṛgvedic account of a total solar eclipse.

Once the conflict between the planet period information and the supposition that the heavens were 1000 earth diameters away became clear, this supposition was dropped. Presumably, the theory that $R_s \approx 500d_e$ was too entrenched by this time and it became the basis from which different Greek and later Indian models emerged. As mentioned before, Ptolemy considers an $R_s$ equal to $600d_e$, whereas Āryabhaṭa assumes it to be about $438d_e$. Thus the Greek and the later Indian modifications to the basic idea proceeded somewhat differently.

The ideas regarding the distance of the sun hardly changed until modern times. The contradictions in the assumption that the luminaries move with uniform mean speed and the requirements imposed by the assumed size of the solar system led to a gradual enlargement of the models of the universe from about twice that of the distance of the sun in *PB* to one $4.32 \times 10^6$ times the distance of the sun by the time of Āryabhaṭa. This inflationary model of the universe in *AAr* makes a distinction between the distance of the sky (edge of the universe) and that of the stars which is taken to be a much smaller sixty times the distance of the sun.

"Beyond the visible universe illuminated by the sun and limited by the sky is the infinite invisible universe" this is stated in a commentary on *AAr* by Bhāskara I writing in 629 CE.[5] The Purāṇic literature from India, part of which is contemporaneous with Āryabhaṭa, reconciles the finite estimates of the visible universe with the old Ṛgvedic notion of an infinite universe by postulating the existence of an infinite number of universes.

It is possible that the original notion that the heavens are $1000d_e$ away from the earth arose as a metaphor for the large extent of the universe, given that a thousand represents a very great size in Indo-European languages. But it is more likely that some measurements and a theory were at the basis of this supposition.

# 9. *The Asymmetric Circuit of the Sun*

## Strings of Wind

In the astronomy of the Śatapatha Brāhmaṇa based on the 10th kāṇḍa of the book (*Agnirahasya*), which was described in Chapter 4, the original fire altar area symbolically represented the lengths of the lunar and its area had to be increased to represent the length of the longer the solar years in a second construction, setting up a process of intercalation. This astronomy included a prescription that 95 such altars be built in a sequence defining a 95-year cycle.

Here we show that the Śatapatha Brāhmaṇa is not limited to intercalation also possessed knowledge of the varying motion of the sun with respect to the four quarters of the year. A hypothesis regarding four different quarters of the year is a natural one to propose as explanation for the difference in temperature during the four seasons.

According to Eggeling,[1] the Śatapatha Brāhmaṇa represents the merging of two traditions, the first 9 kāṇḍas are due to the school of Yājñavalkya and the kāṇḍas 10-14 due to the school of Śāṇḍilya. If one were to accept this theory, then the 95-year lunar-solar cycle of the fire altar astronomy should be called the Śāṇḍilya cycle rather than the Yājñavalkya cycle. But this theory has been rejected by Caland[2] who argues that kāṇḍas 10 is integral to the first nine.

In this chapter we examine the altar designs from Yājñavalkya's 8th kāṇḍa, which have not received sufficient scholarly attention. One design represents the sun's orbit in an asymmetric manner.

We also look at other evidence suggesting sun's non-uniform motion. There were two years: the ritual one started with the winter solstice (*mahāvrata* day), and the civil one started with the spring equinox (*viṣuva*).

The specific asymmetry in the counts between the two halves of the year mentioned in the Brāhmaṇa makes it possible to date these rites and to conclude that they belong to an early period although they were written down much later. This discovery is in consonance with the other astronomical evidence in the Brāhmaṇas and recent archaeological findings. It is possible that the knowledge of the asymmetrical circuit of the sun predates the rites.

The Śatapatha Brāhmaṇa says that the planets are driven by "strings of wind" connected to the sun. This idea, as well as the idea of an offset in the sun's orbit, appear to be behind the development of the notions of the mandocca and śīghrocca cycles of the Siddhāntic astronomy.

## On the Stages of Early Indian Astronomy

It is generally agreed that the Siddhāntic astronomy has unique features which are not to be found in the astronomy of any other nation. In the words of Thurston:[3]

> Not only did Āryabhaṭa believe that the earth rotates, but there are glimmerings in his system (and other similar Indian systems) of a possible underlying theory in which the earth (and the planets) orbits the sun, rather than the sun orbiting the earth. The evidence is that the basic planetary periods are relative to the sun. For the outer planets this is not significant: both earth and sun are inside their orbits and so the time taken to go round the earth and the time taken to go round the sun are the same. The significant evidence comes from the inner planets: the period of the śīghrocca is the time taken by the planet to orbit the sun.

Although Āryabhaṭa is generally credited with the idea of the rotation of the earth, it is not clear that it is so. The rotation of the earth is inherent in the notion that the sun never sets that we find in the Aitareya Brāhmaṇa 2.7:

> The [sun] never really sets or rises. In that they think of him "He is setting," having reached the end of the day, he inverts himself; thus he makes evening below, day above. Again in that they think of him "He is rising in the morning," having reached the end of the night he inverts himself; thus he makes day below, night above. He never sets; indeed he never sets.

One way to visualize it is to see the universe as the hollow of a sphere so that the inversion of the sun shines the light on the world above ours. But this is impossible since the sun does move across the sky during the day and if the sun doesn't set or rise it doesn't move either. Clearly, the idea of "inversion" denotes nothing but a movement of the earth.

Early Vedic sources make it possible for us to see the stages of the development of Indian astronomy. After the Ṛgvedic stage comes the period of the Brāhmaṇas. This is followed by Lagadha's astronomy. The last stage is early Siddhāntic and early Purāṇic astronomy.

These four stages, with their rough time limits, are summarized below:

1. *Ṛgvedic astronomy (c. 4000 - 2000 BCE)* This period is characterized by knowledge of the motions of the sun and the moon, nakṣatras, and planet periods. Much of this knowledge is described as myth. The beginning of this period are lost in the mists of time but we do have references of astronomical events in Vedic stories, like the destruction of the sacrifice of Dakṣa by Śiva, which indicate the era of the fourth millennium BCE.[4] But note that this specific myth belongs to a later stratum of the Vedic myths. The beginning of this period could be much earlier than the hypothetical 4000 BCE we have indicated here.

2. *Astronomy of the Brāhmaṇas (2000 - 1000 BCE)* (Yājñavalkya, Śāṇḍilya) Here we make a distinction between the period of the original rites and the time when the texts were actually written. The astronomy of this period was a natural advance on the earlier Ṛgvedic astronomy. The dating of this period is dictated by its latest material. Its stronomy is represented by means of geometric altars, non-uniform motion of the sun and the moon, intercalation for the lunar year, and "strings of wind joined to the sun."[5]

3. *Vedāṅga Jyotiṣa (c. 1300 BCE)* (Lagadha) The text that has come down to us appears to be of a later era.[6] Being the standard manual for determination of the Vedic rites, Lagadha's work have served as a "living" text in which the language got modified to a later form.

4. *Early Siddhāntic and early Purāṇic (1000 BCE - 500 CE)* Here our main sources are the Śulbasūtras, the Mahābhārata,

> the early Purāṇas, Sūryasiddhānta and other texts. Here occurred further development of the śīghrocca and mandocca cycles, and arose the concept of kalpa.

At the end of these stages stands the classical Siddhāntic period inaugurated by Āryabhaṭa. It is significant that the first three stages are well prior to the rise of mathematical astronomy in Babylonia and in Greece. The concepts of the śīghrocca and mandocca cycles indicate that the motion of the planets was taken to be fundamentally around the sun, which, in turn, was taken to go around the earth.

The mandocca, in the case of the sun and the moon, is the apogee where the angular motion is the slowest and in the case of the other planets it is the aphelion point of the orbit. For the superior planets, the śīghrocca coincides with the mean place of the sun, and in the case of an inferior planet, it is an imaginary point moving around the earth with the same angular velocity as the angular velocity of the planet round the sun; its direction from the earth is always parallel to the line joining the sun and the inferior planet.

The mandocca point serves to slow down the motion from the apogee to the perigee and speed up the motion from the perigee to the apogee. It is a representation of the non-uniform motion of the body, and it may be seen as a direct development of the idea of the non-uniform motion of the sun and the moon.

The śīghrocca maps the motion of the planet around the sun to the corresponding set of points around the earth. This indicates a tradition of heliocentric astronomy as applied to the solar system. The sun, with its winds that hold the solar system together, travels around the earth.

The Sūrya Siddhānta (SS) remembers this pre-epicyclic astronomy of the earlier period. The *uccas* and the node (*pāta*) are thus described in SS 2.1-5:

> Forms of time, of invisible shape, stationed in the zodiac, called the śīghrocca, mandocca, and node (pāta), are causes of the motion of the planets. The planets, attached to these points by cords of air, are drawn away by them, with the right and left hand, forward or backward, according to nearness, toward their own place. A wind, called *pravaha*, impels them toward their own uccas, being drawn away forward and backward.

The antecedents of this system may be seen in the earlier texts. The Ṛgveda (10.136.2) speaks of the stars of the Ursa Major (the Seven Sages) having ropes of wind, (*munayo vāta raśanāḥ*). ŚB 4.1.5.16 describes the sun as *puṣkaramādityo*, "the lotus of the sky." ŚB 8.7.3.10 says:

> *tadasāvāditya imāṃlokāntsūtre samāvayate, tadyattatsūtraṃ vāyuḥ..*
>
> The sun strings these worlds [the earth, the planets, the atmosphere] to himself on a thread. This thread is the same as the wind...

This indicates a central role to the sun in defining the motions of the planets.

## On the Nonuniform Motion of the Sun

With respect to an observer on the earth, the sun has two motions. First, is the daily motion across the sky. Second, is the shifting of the rising and setting directions. It is this second motion which defines the seasons. Its two extreme points are the solstices, and the points where the sun's orbit crosses the equator or when the nights equal the days are the equinoxes.

The Aitareya Brāhmaṇa (4.18) describes how the sun reaches the highest point on the day called viṣuvant and how it stays still for a total of 21 days (the viṣuvant is the middle day of this period). It is almost certain that the number 21 was an arbitrary number, for this was not the only view of the stopping of the sun in the sky. In the Pañcaviṃśa Brāhmaṇa (Chapters 24 and 25), the sun is taken to be more or less still in the heavens for a period of 7 days. There it is described how the viṣuvant day is preceded and followed by three-day periods called svarasāman days.

It was clearly understood that the shifting of the rising and the setting directions had an irregular motion. The numbers 21 and 7 ware normative numbers arising from numerological considerations. Perhaps the number 21 is related to its usage for the earth as well as the sun elsewhere.

ŚB 4.6.2 describes the rite called *gavām ayana*, the "sun's walk" or the "cows' walk." This is a rite which follows the motion of the sun, with its middle of the viṣuvant day.

The Yajurveda (38.20) says that the āhavanīya or the sky altar is four-cornered since the sun is four-cornered, meaning thereby that the motion of the sun is characterized by four cardinal points: the two solstices and the two equinoxes. The āhavanīya altars described in the ŚB are also four-cornered.

With respect to the motion of the sun, ŚB 2.1.3 divides up the year into two halves in two different ways:

> *vasanto grīṣmo varṣāḥ, te devā ṛtavaḥ. śaraddhemantaḥ śiśiraste pitaro ya eva.*
>
> *sa yatrodagāvartate, deveśu tarhi...; yatra dakṣiṇāvartate pitṛṣu tarhi.*
>
> The spring, the summer, and the rains, these seasons (represent) the gods; and the autumn, the winter, and the dewy season represent the fathers.
>
> When he (the sun) moves northwards, then he is among the gods...; and when he moves southwards, then he is among the fathers.

The first classification divides the year from equinox to equinox, whereas the second classification does so from solstice to solstice.

The year-long rites list a total of 180 days before the solstice and another 180 days following the solstice. Since this is reckoning by solar days, it is not clear stated how the remaining 4 or 5 days of the year were assigned. But this may be easily inferred.

Note that the two basic days in this count are the viṣuvant (summer solstice) and the mahāvrata day (winter solstice) which precedes it by 181 days in the above counts. Therefore, even though the count of the latter part of the year stops with an additional 180 days, it is clear that one needs another 4 or 5 days to reach the mahāvrata day in the winter. This establishes that the division of the year was in the two halves of 181 and 184 or 185 days. Corroboration of this is suggested by evidence related to an altar design from ŚB.

The non-uniform motion of the sun should be seen with a similar non-uniform motion of the planets. This non-uniformity is expressed in terms of motion of eight different kinds:

- Vakra (decreasing retrograde)
- Ativakra (increasing retrograde)
- Vikala (stationary)
- Manda (increasing direct motion less than mean motion)

- Mandatara (decreasing direct motion less than mean motion)
- Sama (mean motion)
- Śīghratara or Atiśīghra (increasing direct motion greater than mean motion)
- Śīghra (decreasing direct motion greater than mean motion)

Of these, five motions are direct and two motions are retrograde.

## The Plan of the Altars

The description of the agnicayana, or the building of the fire-altar, begins in the sixth kāṇḍa (book). But rather than speak of the altar of bricks, the text begins with an account of the creation of the universe. The significance of this is that the bricks are just meant to illustrate certain astronomical facts.

In general the numerical and the area equivalences with respect to the bricks and astronomical data are just a means for presenting the facts and it is not clear that the altars were actually constructed. Indeed some of the "bricks" are made out of water or sometimes just loose earth sprinkled on an altar could itself stand for a brick.

Book 7 described the construction of a gārhaptya (householder's) altar. Book 8 describes the construction of the main altar in five layers.

Out of these five layers, the first represents the terrestrial world[7]; the second layer is the near atmosphere[8]; the third layer is the air or the middle atmosphere[9]; the fourth layer is the high atmosphere below the heavens[10]; and the fifth layer is the sky[11]. Note that the first layer is round, for this is the usual representation for the earth; the second layer is square; the third shows the cardinal directions; the fourth is square; and the fifth represents the orbit of the sun.

The five-layered altar is an expansion of the tripartite system of the world:[12] "the first layer is this very (terrestrial) world; and the uppermost (layer) is the sky; and those three (intermediate layers) are the air." These layers are shown in the Figures 9.1 through 9.5.

The fifth layer, the representation of the sky, presents a most interesting overview of the understanding of the physical universe. The details of how the bricks of the fifth layer are to be laid are described in the fifth adhyāya of the 8th kāṇḍa. Note that there are some differences between our Figure 9.5 and that drawn by Eggeling,[13] who has used incorrect sizes for many of the bricks

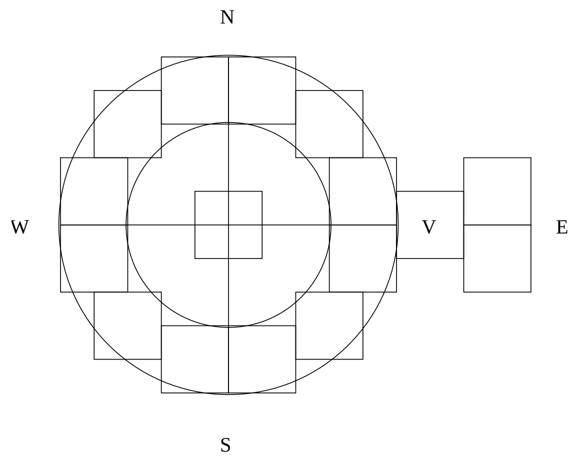



Figure 9.1: Layer 1, the earth

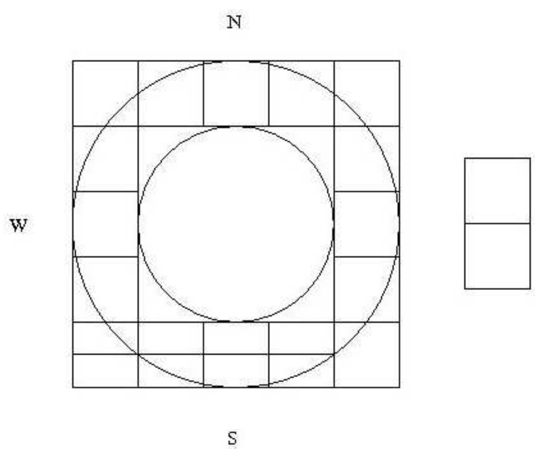



Figure 9.2: Layer 2, the lower atmosphere

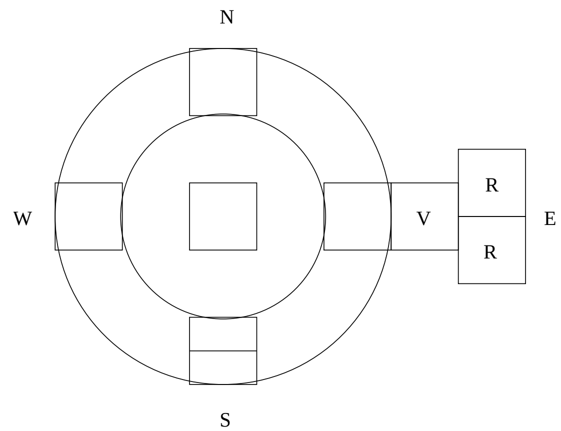



Figure 9.3: Layer 3, the mid-atmosphere

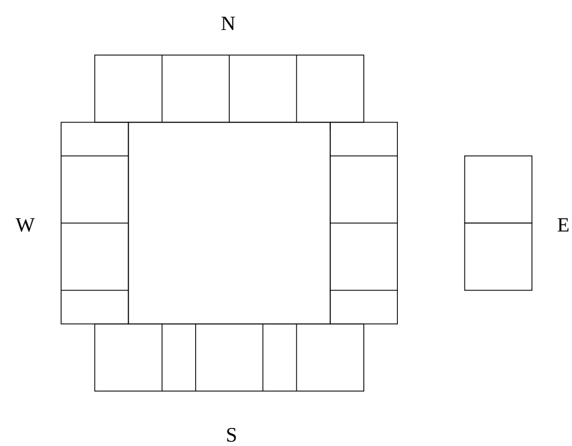



Figure 9.4: Layer 4, the upper atmosphere

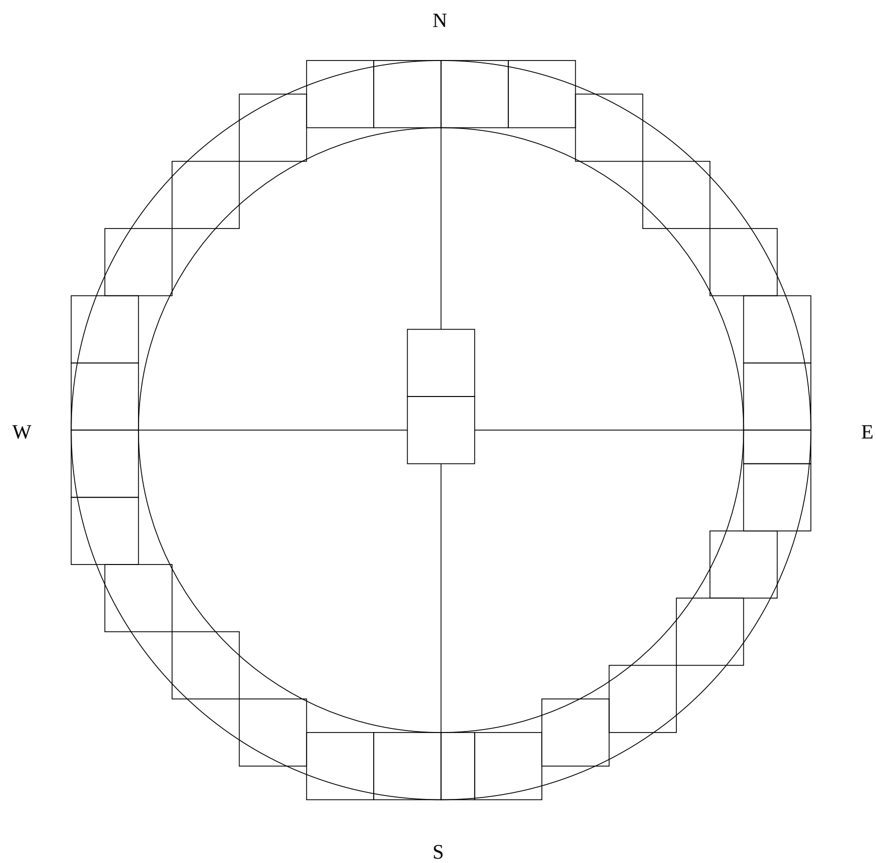



Figure 9.5: Layer 5, the orbit of the sun

that go inside the ring. When the size of each stomabhāgā brick is one unit square, the outer diameter of the ring should be 11 units rather than the 12 units which has been used by Eggeling. This becomes clear when Eggeling's drawing for the fifth layer is compared to those of the first and third layers and we find that the viśvajyoti (V) bricks do not line up as they are supposed to.

The outer rim of layer 5 consists of 29 stomabhāgā bricks. The rest of the layer consists of 5 nākasad upon which are placed 5 pañcacūḍā bricks; chandasyā bricks representing the metres of which three each of triṣṭubh, jagatī, and anuṣṭubh are within the ring of the stomabhāgā bricks. In the middle is the gārhapatya altar of 8 bricks upon which is placed a second layer of 8 bricks called the punaściti. Just within the ring on the east are 2 ṛtavyā, and the lone viśvajyoti (V). Finally, on top of the punaściti are placed two perforated bricks called vikarṇī and svayamātṛṇṇā.

## The Halves of the Year

ŚB 8.5.4.2 calls the stomabhāgās, that form the outer ring of 29 bricks, as "the yonder sun." Note that the gārhapatya altar is placed right in the middle of this ring, and the gārhapatya altar represents the earth. So the layer 5 of Figure 9.5 represents the earth at the center with the sun going around in a circle. Figure 9.6 shows layer 5 with the layer 1 inscribed within.

On top of the central gārhapatya altar, lie the two perforated bricks at an offset to the center. The lower one is at the center. ŚB 8.7.3.9-10 says:

> *atha vikarṇīṃ ca svayamātṛṇṇāṃ copadadhāti, vāyurvai vikarṇī dyauruttamā svayamātṛṇṇā vāyuṃ ca taddivam copadadhātyuttame'upadadhātyuttame hi vāyuśca dyauśca...*
>
> *tadasāvāditya imāṃlokāntsūtre samāvayate, tadyattat sūtraṃ vāyuḥ sa sa yaḥ sa vāyureṣā sā vikarṇī...*
>
> He then lays down the vikarṇī and svayamātṛṇṇā (bricks),—the vikarṇī is Vāyu (the wind), and the svayamātṛṇṇā is the sky: he thus sets up both the wind and the sky. He lays them down as the last (highest), for wind and sky are the highest...
>
> [The] yonder sun strings these worlds [the earth and the atmosphere] to himself on a thread. Now that thread

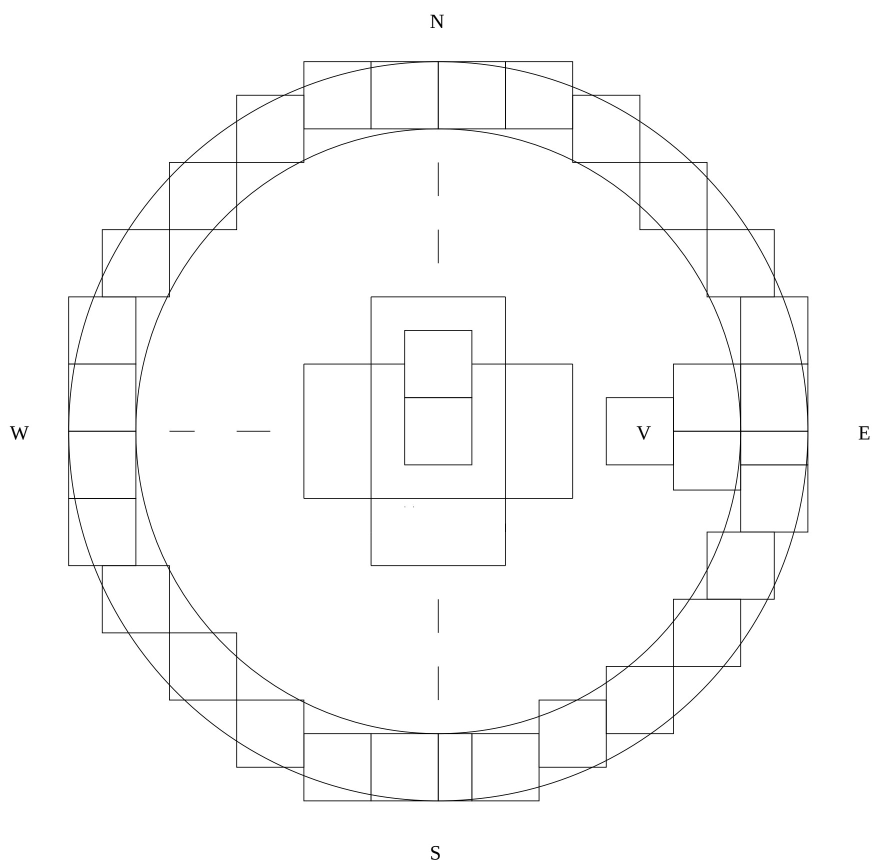



Figure 9.6: The orbit of the sun shown with the earth inscribed within

> is the same as the wind; and that wind is the same as this vikarṇī...

It is almost certain that the meeting point of these two bricks, which is offset from the center of the circle, was taken to be the center of the motion of the sun. The vikarṇī, as the binding force of the sun, will then reach right down to the earth. This inequality would have been easy to discover.

Note that the number of bricks placed in the four quadrants of the circle is not identical. This indicates that the two halves of the year were taken to be unequal.

If one assumes that the two halves of the year are directly in proportional to the brick counts of 14 and 15 in the two halves of the ring of the sun, this corresponds to day counts of 176 and 189. This division appears to have been for the two halves of the year with respect to the equinoxes if we note that the solstices divide the year into counts of 181 and 184.

In reality, the proportion could not be exactly 14:15, and, therefore, any chronological conclusions drawn from this proportion can only be very crude.

The apparent motion of the sun is the greatest when the earth is at perihelion and the least when the earth is at aphelion. Currently, this speed is greatest on January 3. Figure 9.7 presents the current dates for the perihelion and the aphelion. The interval between successive perihelia, the anomalistic year, is 365.25964 days which is 0.01845 days longer than the tropical year on which our calendar is based. In 2,000 calendar years, the date of the perihelion advances about 36 days. Or it advances about 185 days, a half-year, in 10,000 years. The perihelion makes a full cycle, therefore, in about 20,000 years. It is this relative shrinking of the summers and winters which causes ice ages with a period of about 20,000 years.[14]

For a parallel, observe that the Greeks discovered the asymmetry in the quarters of the year around 400 BCE. Euktemon, the supposed discoverer of this asymmetry, speaks of how beginning with the winter solstice he found the four intervals to be 92, 93, 90 and 90 days. Kallippos (c. 370 BCE) improved upon these numbers by proposing 90, 94, 92 and 89 days.

Modern calculations show that at this time, the four quarters of the year starting with the winter solstice were 90.4, 94.1, 92.3, and 88.6 days long. The period from the winter solstice to the summer solstice was then 184.5 days and the perihelion occurred more than

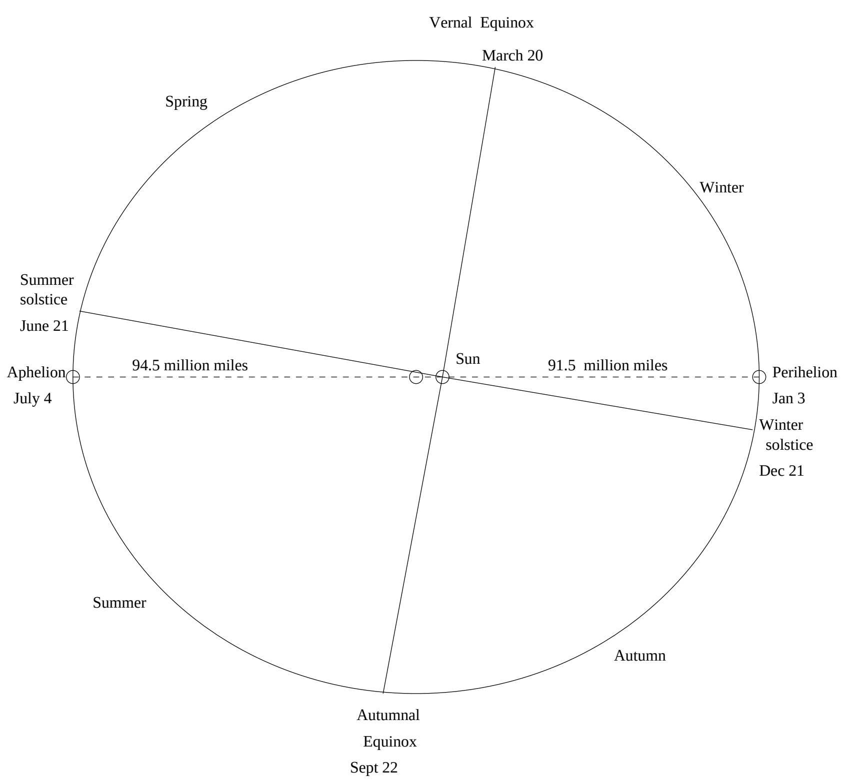



Figure 9.7: The current dates of the perihelion and the aphelion

a month prior to the winter solstice.

Considering the rites of the Brāhmaṇas it is best to assume that the insistence that there were exactly 180 days from the winter to the summer solstice is an idealization. Apparently, the basis of this count was the observation that the period from the winter to the summer solstice was shorter than the corresponding period from the summer to the winter solstice. The approximate equality of these two halves of the year would occur when the perihelion is at either of the two solstices. Now, the perihelion was at the winter solstices in 1200 CE, but that is too late to have been the basis of the observations. The other possibility is that during the rites the perihelion occurred prior to June 21, but this was true only before about 8800 BCE.

This gives periods which are too early for the rites described in the Brāhmaṇas. But there is no reason to doubt that the ancient Indians found that the two halves of the year were asymmetric. From the observations of the Greeks, this asymmetry between the two halves of the year during the 1st millennium BCE was just the opposite of what we find in the Brāhmaṇas. These texts describe rites which belong to a much earlier age. How much earlier we cannot be certain of at this time given the uncertainty regarding the chronology of early India.

A distinction should be made between the period of the rites and the time that these rites were written down. It is common for a religious tradition to be practised even after the astronomical basis for it ceases to have any meaning. For example, the biblical account of the creation of the universe in seven days may have been true in a metaphorical sense where each day represents the creation of one of the planets, but three thousand years after the origination of this myth there are people who believe in it literally.

It is natural to assume that the myths of the ancient people were already very old when they were written. This point was made and substantiated by de Santillana and von Dechend while talking about the knowledge of precession. Given that the beginning of the Indian tradition have been traced back to at least 8000 BCE in Mehrgarh in an unbroken tradition, this is likely to be true for India also.

We can be certain that the date of first millennium BCE for the rites of the Brāhmaṇas is incorrect. We conservatively propose 2nd millennium BCE as the period when the Brāhmaṇas were codified. This is supported by other evidence in these texts which refers to the 3rd and the 2nd millennia BCE.

Once the notion of the non-uniform motion of the sun had taken root, the idea of the apogee exercising a slowing force was a natural development.

The knowledge of the orbit of the sun, together with the discovery of Yājñavalkya harmonizing the solar and the lunar years by the 95-year intercalary cycle, provides an explanation for the legend that Yājñavalkya was *inspired* by the sun.

The design of the altar of layer 5 confirms that the year was divided into two parts: winter solstice to summer solstice of 181 days, and midsummer-to-midwinter of 184 or 185 days.

The theory that the sun was the "lotus" [the central point] of the sky and that it kept the worlds together by its "strings of wind" gave rise to a heliocentric tradition in India. The offset of the sun's orbit evolved into the notion of mandocca and the motions of the planets around the sun were transferred to the earth's frame through the device of the śīghrocca.

# *10. The Vedāṅga Jyotiṣa*

## Introduction

The astronomical text of the Vedāṅga Jyotiṣa (VJ) was in use during the times of the altar ritual. VJ has an internal date of about c. 1300 BCE, give and take a couple of centuries,[1] obtained from its assertion that the winter solstice was at the asterism Śraviṣṭhā (Delphini). Recent archaeological discoveries support such an early date, and so this text is important for the understanding of practical (ritual-based) Vedic astronomy.

The ritual-based astronomy was concerned only with the motions of the sun and the moon and the fixing of various observances within the cycle of the year. As a practical manual used by the priests, VJ covers limited ground which explains why it does not discuss the positions of stars.

## The Motions of the Sun and the Moon

The *Vedāṅga Jyotiṣa* manual is available in two recensions: the earlier Ṛgvedic VJ (RVJ) and the later Yajurvedic VJ (YVJ). RVJ has 36 verses and YVJ has 43 verses.

The measures of time used in VJ are as follows:

1 lunar year = 360 tithis
1 solar year = 366 solar days
1 day = 30 muhūrtas
1 muhūrta = 2 nāḍikās
1 nāḍikā = $10\frac{1}{20}$ kalās
1 day = 124 aṁśas (parts)
1 day = 603 kalās

Five years were taken to equal a *yuga*. A ordinary yuga consisted of 1,830 days. An intercalary month was added at half the yuga and another at the end of the yuga.

What are the reasons for the use of a time division of the day into 603 kalās? This is explained by the assertion VJ 29 that the moon travels through 1,809 nakṣatras in a yuga. Thus the moon travels through one nakṣatra in $1\frac{7}{603}$ sidereal days because

$$1,809 \times 1\frac{7}{603} = 1,830.$$

Or the moon travels through one nakṣatra in 610 kalās. Also note that 603 has 67, the number of sidereal months in a yuga, as a factor The further division of a kalā into 124 kāṣṭhās was in symmetry with the division of a yuga into 62 synodic months or 124 fortnights (of 15 tithis), or parvans. A parvan is the angular distance traveled by the sun from a full moon to a new moon or vice versa.

The ecliptic was divided into twenty seven equal parts, each represented by a nakṣatra or constellation. The VJ system is a coordinate system for the sun and the moon in terms of the 27 nakṣatras. Several rules are given so that a specific tithi and nakṣatra can be readily computed.

> The number of risings of the asterism Śraviṣṭhā in the yuga is the number of days plus five (1830+5 = 1835). The number of risings of the moon is the days minus 62 (1830-62 = 1768). The total of each of the moon's 27 asterisms coming around 67 times in the yuga equals the number of days minus 21 (1830-21 = 1809). (YVJ 29)

> The moon is conjoined with each asterism 67 times during a yuga. The sun stays in each asterism $13\frac{5}{9}$ days. (RVJ 18, YVJ 39)

The explanations are straightforward. The sidereal risings equals the 1,830 days together with the five solar cycles. The lunar cycles equal the 62 synodic months plus the five solar cycles. The moon's risings equal the risings of Śraviṣṭhā minus the moon's cycles.

This indicates that the moon was taken to rise at a mean rate of

$$\frac{1,830}{1,768} = 24 \textit{ hours and } 50.4864 \textit{ minutes.}$$

## Computation of tithis, nakṣatras, kalās

Although we spoke of the mean tithi related through the lunar year equalling 360 tithis, the determination of a tithi each day is by a calculation of a shift of 12° with respect to the sun. In 30 tithis, the moon covers the full circle of 360°. But the shift of 12° is in an irregular manner and the duration of the tithi can vary from day to day. As a practical method, the mean tithi can be defined by a formula. In terms of kalās, a tithi is approximately 593 kalās. VJ takes it to be 122 parts of the day divided into 124 parts (RVJ 22, YVJ 37, 40).

Each yuga was taken to begin with the asterism Śraviṣṭhā and the synodic month of Māgha, the solar month Tapas and the bright fortnight (parvan), and the northward course of the sun and the moon (RVJ 5-6; YVJ 6-7). The intercalary months were used in a yuga. But since the civil year was 366 days, or 372 tithis, it was necessary to do further corrections. As shown in an earlier chapter, a further correction was performed at 95 year, perhaps at multiples of 19 years.

The day of the lunar month corresponds to the tithi at sunrise. A tithi can be lost whenever it begins and ends between one sunrise and the next. Thus using such a mean system, the days of the month can vary in length.

### Rule on End of parvan

The determination of the exact ending of the synodic fortnight (parvan) is important from the point of view of the performance of ritual. Let $p$ be the parvans that have elapsed from the beginning of the yuga. Since each parvan has 1,830 parts, the number of parts, $b$, remaining in the day at the end of $p$ parvans is:

$$b = 1830\ p\ mod\ 124.$$

Now consider

$$p\ mod\ 4 = \alpha,$$

and

$$1830\ mod\ 31 = 1.$$

By multiplying the two modular equations, it can be easily shown that

$$b = (1829 \times \alpha + p) mod\ 124.$$

By substituting the values $\alpha = 1, 2, 3$ we get the YVJ 12 rule:

When $\alpha = 1$, b = p + 93 mod 124;
when $\alpha = 2$, b = p + 62 mod 124;
when $\alpha = 3$, b = p + 31 mod 124.

### Rule on nakṣatra parts

The nakṣatra part of the sun at the end of the $p$th parvan, $s$, is clearly:

$$s = 135\ p\ mod\ 124.$$

This is because 124 parvans equal the 135 nakṣatra segments for the sun at the end of the yuga of 5 years. Let $p = 12 \times q + r$. Then we can write:

$$135\ p\ mod\ 124 = 11 \times (12q + r) = 8q + 11r\ mod\ 124.$$

This is the rule described to compute the nakṣatras of the sun (RVJ 10, YVJ 15).

If the moon is full, it will be in opposition to the sun and, therefore, $13\frac{1}{2}$ segments, or 13 nakṣatras and 62 parts away. The rule further states that for a full moon its nakṣatra parts are computed by adding 62 to the parts obtained for the sun. This can be seen directly by noting that the nakṣatra parts of the moon, $m$, will be according to:

$$m = 1809\ p\ mod\ 124.$$

This leads to the equation:

$$m = 8q + 73r\ mod\ 124.$$

This is in excess from $s$ by $62r\ mod\ 124$, which is 62 when $p$ is odd.

### Moon nakṣatra in kalās

Since 124 parvans correspond to 1,809 or 67 × 27 nakṣatras, 17 parvans correspond to $248 + \frac{1}{124}$ nakṣatras. Now the moon passes through each nakṣatra in 610 kalās, therefore the 248 days correspond to $\frac{248 \times 610}{603}$ days; this equals 250 days and 530 kalās. If we assume that we are just one part short of the 16th parvan, we have its modular relationship with 530 kalās. For 8 nakṣatra parts short, this corresponds to $530 \times 8\ mod\ 603 = 19$ kalās. Each part is -73 kalās. This rule is in RVJ 11 and YVJ 19.

**Other Rules and Accuracy**

There are other rules of a similar nature which are based on the use of congruences. These include rules on hour angle of nakṣatras, time of the day at the end of a tithi, time at the beginning of a nakṣatra, correction for the sidereal day, and so on. It follows that the use of mean motions can lead to discrepancies that need to be corrected at the end of the yuga.

The VJ system could only serve as a framework. It appears that there were other rules of missing days that brought the calendar into consonance with the reality of the nakṣatras at the end of the five year yuga and at the end of the 95 year cycle of altar construction.

The approximations built into VJ arose from the consideration of the civil year to be 366 days and the consideration of a tithi as being equal to $\frac{122}{124}$ of a day. The error between the modern value of tithi and its VJ value is:

$$\frac{354.367}{360} - \frac{122}{124}$$

which is as small as $5 \times 10^{-4}$. This leads to an error of less than a day in a yuga of five years.

Mean motion astronomy can lead to significant discrepancy between true and computed values. The system of intercalary months introduced further irregularity into the system. The conjunction between the sun and the moon that was assumed at the beginning of each yuga became more and more out of joint until such time that the major extra-yuga corrections were made.

## Mathematical Ideas

Apart from concerns of geometry and astronomy the Śatapatha Brāhmaṇa (ŚB) deals with the question of all the divisors of a number. The counting of the number of divisors suggests that the concept of primality was known at that time.

The Śulbasūtras give geometric solutions of linear equations in a single unknown. They also deal with quadratic equations of the forms $ax^2 = c$ and $ax^2 + bx = c$. Baudhāyana's Śulbasūtra gives a remarkable approximation to $\sqrt{2}$:

$$\sqrt{2} = 1 + \frac{1}{3} + \frac{1}{3 \times 4} - \frac{1}{3 \times 4 \times 34} = \frac{577}{408}$$

This is accurate to five decimal places. It is intriguing that Baudhāyana felt the need to add the last term in the expansion because without that the approximation is still valid to three decimal places and excellent for most geometric constructions.

The motivation for the mathematics of the Śulbasūtras is the solution to problems of altar construction. Some of these constructions are squaring a circle (derived from the equivalence of the circular earth altar and the square sky altar) and construction of a geometric design of a larger size by increasing the dimensions. Since in the actual construction of such altars the accuracy of the above expansion of $\sqrt{2}$ would not have been noticed, it is clear that Baudhāyana was interested in mathematical problems and properties of numbers.

The Śulbasūtras belong to the Vedāṅgas, or supplementary texts of the Vedas. Although they are part of the Kalpa Sūtras, which deal with ritual, their importance stems from the constructions they provide for building geometric altars. Their contents, written in the condensed sūtra style, include geometrical propositions and problems related to rectilinear figures and their combinations and transformations, squaring the circle, as well as arithmetical and algebraic solutions to these problems. The root *śulb* means measurement, and the word "śulba" means a cord, rope, or string.

The extant Śulbasūtras belong to the schools of the Yajurveda. The most important Śulba texts are the ones by Baudhāyana, Āpastamba, Kātyāyana, and Mānava. They have been generally assigned to the period 800 to 500 BCE, although they are likely to be older. Baudhāyana's text is the oldest, and he begins with units of linear measurement and then presents the geometry of rectilinear figures, triangles, and circles, and their transformations from one type to another using differences and combinations of areas. An approximation to the square root of 2 and to $\pi$ are next given.

Then follow constructions for various kinds of geometric altars in the shapes of the falcon (both rectilinear and with curved wings and extended tail), kite, isosceles triangle, rhombus, chariot wheel with and without spokes, square and circular trough, and tortoise.

In the methods of constructing squares and rectangles, several examples of Pythagorean triples are provided. It is clear from the constructions that both the algebraic and the geometric aspects of the so-called Pythagorean theorem were known. This knowledge precedes its later discovery in Greece. The other theorems in the Śulba include:

- The diagonals of a rectangle bisect each other.
- The diagonals of a rhombus bisect each other at right angles.
- The area of a square formed by joining the middle points of the sides of a square is half of the area of the original one.
- A quadrilateral formed by the lines joining the middle points of the sides of a rectangle is a rhombus whose area is half of that of the rectangle.
- A parallelogram and rectangle on the same base and within the same parallels have the same area.
- If the sum of the squares of two sides of a triangle is equal to the square of the third side, then the triangle is right-angled.

A variety of constructions are listed. Some of the geometric constructions in these texts are based on algebraic solutions of simultaneous equations, both linear and quadratic. It appears that geometric techniques were often used to solve algebraic problems.

The Śulbas are familiar with fractions. Algebraic equations are implicit in many of their rules and operations. For example, the quadratic equation and the indeterminate equation of the first degree are a basis of the solutions presented in the constructions.

## Kinds of Time

Since VJ is a manual on time keeping, it is instructive to see the wider context in which time was considered in the Vedic tradition.

The Sūrya Siddhānta 1.10 speaks of two kinds of time, one continuous and endless (which is the cause of creation and destruction on the large scale), and the second which can be known. The second kind has two types called mūrta (measurable) and amūrta (immeasurable, because of the smallness of its duration).

The mūrta time sequence begins with prāṇa. The amūrta time represents smaller intervals beginning with truṭi.

6 prāṇa = 1 vināḍī
60 vināḍī = 1 nāḍī (ghaṭikā)
60 ghaṭikās = 1 nākṣatra ahorātra (sidereal day and night)
30 nākṣatra ahorātras = 1 nākṣatra māsa (sidereal month))

30 sāvana (terrrestrial) days = 1 sāvana month

The nāḍī means pulse, and ghaṭikā refers to the water clock. The Atharvaveda mentions the use of water-clock for timekeeping.

The number of lunar months is equal to the difference between the revolutions of the moon and those of the sun, and the remainder of the lunar months lessened by the solar months is the number of *adhimāasas* (SS 1.35).

If the sāvana (terrestrial) days are subtracted from teh lunar days, the remainder constitute the days called the *tithi-kṣaya*. There the sāvana days are those in which it is equal to the time from sunrise to sunrise at the equator (SS 1.36).

Table 10.1: Types of Year

| Type of Year | Determinant of the Day |
|---|---|
| Nākṣatra | Revolution of the earth |
| Sāvana | Sunrise to sunrise |
| Lunar | Tithi |
| Saura | One degree of the sun's motion |

## From Altar to Temple

The astronomy of the Vedāṅga Jyotiṣa could be used as a template against which other priestly book-keeping of time may be examined. It raises the question if ritual altars in Babylon, Greece, and Rome were similarly used. The Greek references to geometric problems related to altars need to be investigated in this new light.

Fire altars were used extensively in several parts of Eurasia, but records giving details of the geometric altar designs are available only from India. The altar ritual in Iran was very similar to that of India.

There was also a connection between monumental architecture and astronomy that can be seen from the temples and pyramids from Egypt, the temples of Mesopotamia, and megalithic monuments such as Stonehenge. Manuals of temple design from India spell this out most clearly. An Indic temple is a representation of the universe.

That science in Greece had an origin in ritual is based on the remarks of Plutarch (*Epicurum IX*) that Pythagoras sacrificed an ox when he discovered the theorem named after him. Some have argued that this legend is, in all probability, false since Pythagoras was opposed to killing and sacrificing of animals, especially cattle. Nevertheless, this story frames the connection between ritual and science in the ancient world.

Plutarch says elsewhere (*Quaestiones Convivii, VIII*, Quaest. 2.4) that the sacrifice of the bull was in connection with the problem of constructing a figure with the same area as another figure and a shape similar to a third figure.

It is generally accepted that Hipparchus discovered precession in 127 BCE. The magnitude calculated by Hipparchus and used by Ptolemy was 1 degree in 100 years. The true value of this precession is about 1 degree in 72 years. Clearly the discovery of precession could not have been made based on observations made in one lifetime. The ancient world marked seasons with the heliacal rising of stars. Thus Hipparchus must have based his theory regarding precession on an old tradition.

Late religious architecture, both in the east and the west, became more abstract but its astronomical inspiration was never hidden. In Europe cathedrals were a representation of the vault of heavens. In India the temple architecture, as spelt out in the manuals of the first centuries CE, symbolizes the sky where in addition to equivalence by number or area, equivalence by category was considered. The temple platform was generally divided into 64 or 81 squares (Figure 10.1). In the case of the 64-squared platform, the outer 28 squares represented the 28 lunar mansions of the Indic astronomy.

For the 81-squared platform, the outer 32 squares were taken to represent the lunar mansions and the four planets who rule over the equinoctial and solstitial points. Stella Kramrisch, the renowned scholar of Indian temple architecture, has also argued that another measure in the temple was that of 25,920, the number of years in the period of the precession of the equinoxes.[2]

One can see a plausible basis behind the equivalences between the astronomical, terrestrial and physiological phenomena.[3] Research has shown that all life comes with its inner clocks. Living organisms have rhythms that are matched to the periods of the sun or the moon.

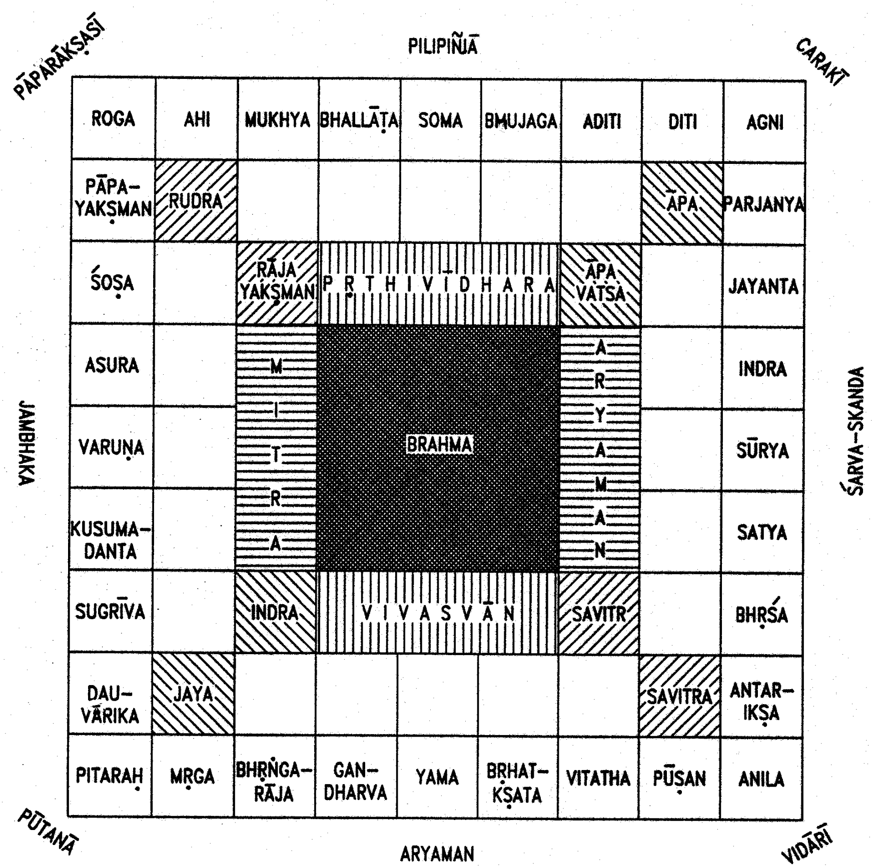



Figure 10.1: The cosmic plan of the classical temple

# 11. *The Cosmology of the Purāṇas*

## Speed of the Sun

The importance of the sun in the scheme of Vedic knowledge comes from the assumed homology between the outer and the inner. Is this homology to be conceived in a sense that is more than the metaphorical? If there are perceived shells to our psychological being, are these mirrored in the structure of the physical cosmos? Does the sun hold the cosmos together just as the inner sun of consciousness defines the individual? This chapter addresses these questions by presenting an astonishing coincidence from the Vedic tradition related to the speed of light.

Indian texts consider light to be like wind suggesting that finite speed was associated with it. Light-wind was seen in analogy with the breath (prāṇa) within the body. The Purāṇas speak of the moving *jyotiścakra*, "the circle of light." This analogy or that of the swift arrow let loose from the bow in these accounts leaves ambiguous whether the circle of light is the sun or its speeding rays.

We get a specific number that equals the speed of light in a medieval text by Sāyaṇa (c. 1315-1387 CE), Vedic scholar and prime minister in the court of Emperors Bukka I and his successors of the Vijayanagara Empire. In his commentary on the fourth verse of the hymn 1.50 of the Ṛgveda on the sun, he says[1]

> *tathā ca smaryate yojanānāṃ sahasre dve dve śate dve ca yojane ekena nimiṣārdhena kramamāṇa*

> Thus it is remembered: [O sun] you who traverse 2,202 *yojanas* in half a *nimeṣa*.

The same statement occurs in the commentary on the Taittirīya Brāhmaṇa by Bhaṭṭa Bhāskara (10th century CE?), where it is said to be an old Purāṇic tradition.

The figure could refer to the actual motion of the sun but, as we will see shortly, that is impossible. Is it an old tradition related to the speed of [sun]light that Sāyaṇa suggests? We would like to know if that supposition is true by examining parallels in the Purāṇic literature.

The units of *yojana* and *nimeṣa* are well known. The usual meaning of yojana is about 9 miles as in the *Arthaśāstra* where it is defined as being equal to 8,000 *dhanus* or "bow," where each dhanus is taken to be about 6 feet. Āryabhaṭa, Brahmagupta and other astronomers used smaller yojanas but such exceptional usage was confined to astronomers; we will show that the Purāṇas also use a non-standard measure of yojana. As a scholar of the Vedas and a non-astronomer, Sāyaṇa would be expected to use the "standard" Arthaśāstra units. More recently, it has become possible to define yojana accurately by considering the standard equation that one dhanus is 108 aṅgula and the latter is 1.763 cm based on evidence from the Harappan sites. This gives a value of yojana that is about 4 percent higher than given by the dhanus equated to 6 feet.

The measures of time are thus defined in the Purāṇas (ViP 1.3.3):

15 nimeṣa = 1 kāṣṭhā

30 kāṣṭhā = 1 kalā

30 kalā = 1 muhūrta

30 muhūrta = 1 day-and-night

A nimeṣa is therefore equal to $\frac{16}{75}$ seconds.

De and Vartak[2] argued that this statement refers to the speed of light. Converted into modern units, it does come very close to the correct figure of roughly 186,000 miles per second (or 300,000 kilometers per second)!

Such an early knowledge of this number doesn't sound credible because the speed of light was determined only in 1675 by Roemer who looked at the difference in the times that light from Io, one of the moons of Jupiter, takes to reach the earth based on whether it is on the near side of Jupiter or the far side. Until then, in Europe, light was taken to travel with infinite velocity. There is no record of any optical experiments that could have been performed in India before the modern period to measure the speed of light.

Maybe Sāyaṇa's figure refers to the speed of the sun in its supposed orbit around the earth. But that places the orbit of the sun at a distance of over 2,550 million miles. The correct value is only 93 million miles and until the time of Roemer the distance to the sun used to be taken to be less than 4 million miles. This interpretation takes us nowhere. The Indian astronomical texts place the sun only about half a million yojanas from the earth.

What about the possibility of fraud? Sāyaṇa's statement was printed in 1890 in the edition of Ṛgveda edited by Max Müller, the German Sanskritist. He claimed to have used several of the three or four hundred year old extant manuscripts of Sāyaṇa's commentary, written much before the time of Roemer.

Is it possible that Müller was duped by an Indian correspondent who slipped in the line about the speed? Unlikely, because Sāyaṇa's commentary is so well known that an interpolation would have been long discovered. And soon after Müller's "Rigveda" was published, someone would have claimed that it contained this particular "secret" knowledge. Besides, a copy of Sāyaṇa's commentary, dated 1395, is preserved in the Central Library, Vadodara.[3]

One can dismiss Sāyaṇa's number as a meaningless coincidence. But that would be a mistake if there exists a framework of ideas—an old physics—in which this number makes sense. We explore the prehistory of this number by considering early textual references. We will show that these references in the Purāṇas and other texts indicate that Sāyaṇa's speed is connected, numerically, to very ancient ideas.

## Physical Ideas

The Vedas take the universe to be infinite in size. The universe was visualized in the image of the cosmic egg, *Brahmāṇḍa*. Beyond our own universe lie other universes.

The Pañcaviṃśa Brāhmaṇa 16.8.6 states that the heavens are 1000 earth diameters away from the earth and that the sun is halfway to the heavens. The Yajurveda, in the mystic hymn 17, dealing with the nature of the universe, counts numbers in powers of ten upto $10^{12}$. It has been suggested that this is an estimate of the size of the universe in yojanas.

The philosophical schools of Sāṃkhya and Vaiśeṣika tell us about the old ideas on light.[4] According to Sāṃkhya, light is one of the five fundamental "subtle" elements (*tanmātra*) out of which emerge the gross elements.

In Vaiśeṣika, the atomic physical world rests on the nonatomic ground of ether, space and time. The basic atoms are those of earth (*pṛthivī*), water (*āpas*), fire (*tejas*), and air (*vāyu*), which should not be confused with the ordinary meaning of these terms. These atoms are taken to form binary molecules that combine further to form larger molecules.[5] Motion is defined in terms of the movement of the physical atoms and it is taken to be non-instantaneous.

Light rays are a stream of high velocity of tejas atoms. The particles of light can exhibit different characteristics depending on the speed and the arrangements of the tejas atoms.

Purāṇic astronomy is cryptic, and since the Purāṇas are encyclopaedic texts, with several layers of writing, presumably by different authors, there are inconsistencies in the material. The origins of Purāṇic cosmology may be seen in Yājñavalkya's concentric model in the Bṛhadāraṇyaka Upaniṣad (BU 3.3.2),[6] wherein it is said: "Thirty-two times the space traversed by the suns chariot in a day makes this plane (loka); around it, covering twice the area, is the world (pṛthivī); around the world, covering twice the area, is the ocean." Sometimes, speculative and empirical ideas are so intertwined that without care the material can appear meaningless. Purāṇic geography is quite fanciful and this finds parallels in its astronomy as well.

We can begin the process of understanding Purāṇic astronomy by considering its main features, such as the size of the solar system and the motion of the sun. But before we do so, we will speak briefly of the notions in the Siddhāntas.

## Universe Size in the Āryabhaṭīya

Āryabhaṭa in his *Āryabhaṭīya (AAr)* deals with the question of the size of the universe. He defines a *yojana* to be 8,000 *nṛ*, where a *nṛ* is the height of a man; this makes his yojana ($y_a$) approximately 7.5 miles.[7] Or $y_s \approx \frac{6}{5} y_a$, where $y_s$ is the standard Arthaśāstra yojana. AAr 1.6 states that the orbit of the sun is 2,887,666.8 *yojanas* and that of the sky is 12,474,720,576,000 *yojanas.*

Commenting on this, Bhāskara I (c. 629) says:[8]

> *yāvantamākāśapradeśam ravermayūkhāḥ samantāt dyotayanti tāvān pradeśaḥ khagolasya paridhiḥ khakakṣyā. anyathā hyaparimitatvāt ākāśasya parimāṇākhyānam nopa-*

> *padyate.*
>
> That much of the sky as the sun's rays illumine on all sides is called the orbit of the sky. Otherwise, the sky is beyond limit; it is impossible to state its measure.

This implies that while the universe is infinite, the solar system extends as far as the rays of the sun can reach.

There is no mention by Āryabhaṭa of speed of light. But the range of light particles is taken to be finite, so it must have been assumed that the particles in the "observational universe" do not penetrate to the regions beyond the "orbit of the sky." This is seen in the analogy of the gravitational pull of matter that makes particles fall back on earth after reaching a certain height.

The orbit of the sky is $4.32 \times 10^6$ greater than the orbit of the sun indicating that this enlargement was inspired by cosmological ideas.

The diameters of the earth, the sun, and the moon are taken to be 1,050, 4,410 and 315 yojanas, respectively. Furthermore, *AAr* 1.6 implies the distance to the sun, $R_s$, to be 459,585 yojanas, and that to the moon, $R_m$, as 34,377 yojanas. These distances are in the correct proportion related to their assumed sizes given that the distances are approximately 108 times the corresponding diameters.

Converted to the standard *Arthaśāstra* units, the diameters of the earth and the sun are about 875 and 3,675 yojanas, and the distance to the sun is around 0.383 million yojanas.

Āryabhaṭa considers the orbits, with respect to the earth, in the correct order Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn, based on their periods.

## Purāṇic Cosmology

The Purāṇas provide material which is believed to be closer to the knowledge of the Vedic times. Here we specifically consider Vāyu Purāṇa (VaP), Viṣṇu Purāṇa (ViP), and Matsya Purāṇa (MP). VaP and ViP are generally believed to be amongst the earliest Purāṇas and at least 1,500 years old. Their astronomy is prior to the Siddhāntic astronomy of Āryabhaṭa and his successors.

The Purāṇas instruct through myth and this mythmaking may be seen in their approach to astronomy. For example, they speak of seven underground worlds below the orbital plane of the planets and of seven "continents" encircling the earth. One has to take care to separate this imagery, that parallels the conception of the seven centers of the human's psycho-somatic body, from the cosmology of the Purāṇas in their *jyotiṣa* chapters.

The idea of seven regions of the universe is present in the Ṛgveda 1.22.16-21 where the sun's stride is described as *saptadhāman*, or taking place in seven regions.

The different Purāṇas appear to reproduce the same cosmological material. There are some minor differences in figures that may be a result of wrong copying by scribes. Here, we mainly follow ViP.

ViP 2.8 describes the sun to be 9,000 yojanas in length and to be connected by an axle that is $15.7 \times 10^6$ yojanas long to the Mānasa mountain and another axle 45,500 yojanas long connected to the pole star. The distance of 15.7 million yojanas between the earth and the sun is much greater than the distance of 0.38 or 0.4375 million yojanas that we find in the Siddhāntas. This greater distance is stated without a corresponding change in the diameter of the sun. It is interesting that this distance is less than one and a half times the correct value; the value of the Siddhāntas is one-thirtieth the correct value.

Elsewhere, in VaP 50, it is stated that the sun covers 3.15 million yojanas in a muhūrta. This means that the distance covered in a day are 94.5 million yojanas. MP 124 gives the same figure. This is in agreement with the view that the sun is 15.7 million yojanas away from the earth. The specific speed given here, translates to 116.67 yojanas per half-nimeṣa.

The size of the universe is described in two different ways, through the "island-continents" and through heavenly bodies.

The geography of the Purāṇas describes a central continent, Jambu, surrounded by alternating bands of ocean and land. The seven island-continents of Jambu, Plakṣa, Śālmala, Kuśa, Kraunca, Śāka, and Puṣkara are encompassed, successively, by seven oceans; and each ocean and continent is, respectively, of twice the extent of that which precedes it. The universe is seen as a sphere of size 500 million yojanas.

The continents are imaginary regions and they should not be confused with the continents on the earth. Only certain part of the innermost planet, Jambu, that deals with India has parallels with real geography.

The inner continent, with size of 16,000 yojanas, is the base of the world axis. In opposition to the interpretation by earlier commentators, who took the increase in dimension by a factor of two only across the seven "continents," we take it to apply to the "oceans" as well. We do so because it harmonizes many numbers. In itself, it has no bearing on the question of the speed of light that we will discuss later.

At the end of the seven island-continents is a region that is twice the preceding region. Further on, is the Lokāloka mountain, 10,000 yojanas in breadth, which marks the end of our universe.

Assume that the size of the Jambu is $J$ yojana, then the size of the universe is:

$U = J(1+2+2^2+2^3+2^4+2^5+2^6+2^7+2^8+2^9+2^{10}+2^{11}+2^{12}+2^{13}+2^{14})+20,000$

Or,

$$U = 32,767J + 20,000 \; yojanas \qquad (11.1)$$

If U is 500 million miles, then J should be about 15,260 yojanas. The round figure of 16,000 is mentioned as the width of the base of the Meru, the world axis, at the surface of the earth which supports our interpretation. Our calculation assumes that around the Meru of size 16,000 yojanas is the rest of the Jambu continent which circles another 16,000 yojanas. In other words, it takes the diameter of Jambu to be about 48,000 yojanas.

This analysis explains that the description of Purāṇic cosmology was thought to be inconsistent because an erroneous interpretation of the increase in the sizes of the "continents" was used.

When considered in juxtaposition with the preceding numbers, the geography of concentric continents is a representation of the plane of the earth's rotation, with each new continent as the orbit of the next "planet."

The planetary model in the Purāṇas is different from that in the Siddhāntas. Here the moon as well as the planets are in orbits higher than the sun. Originally, this supposition for the moon may have represented the fact that it goes higher than the sun in its orbit. Given that the moon's inclination is 5° to the ecliptic, its declination can be 28.5° compared to the sun's maximum declination of ±23.5°. This "higher" position must have been, at some stage, represented literally by a higher orbit. To make accord with observational reality, it became necessary for the moon to taken to be twice as large as the sun.

The distances of the planetary orbits beyond the sun are given in Table 1. In this fanciful visualization the sun is very far from the earth and the moon and other planets are near the sun. The universe is viewed as a hollow sphere in which the earth is at the center and the sun and the planets are clumped together; beyond them is the vast region of other worlds of Table 2. This universe is a cosmic mapping of the individual's body.

Table 1: From Earth to Pole-star

| Interval I | yojanas |
|---|---:|
| Earth to Sun | 15,700,000 |
| Sun to Moon | 100,000 |
| Moon to Asterisms | 100,000 |
| Asterisms to Mercury | 200,000 |
| Mercury to Venus | 200,000 |
| Venus to Mars | 200,000 |
| Mars to Jupiter | 200,000 |
| Jupiter to Saturn | 200,000 |
| Saturn to Ursa Major | 100,000 |
| Ursa Major to Pole-star | 100,000 |
| Sub-total | 17,100,000 |

The regions beyond the pole-stare are the Maharloka, the Janaloka, the Tapoloka, and the Satyaloka. Their distances are as follows:

Table 2: From Pole-star to Satyaloka

| Interval II | yojanas |
|---|---:|
| Pole-star to Maharloka | 10,000,000 |
| Maharloka to Janaloka | 20,000,000 |
| Janaloka to Tapoloka | 40,000,000 |
| Tapoloka to Satyaloka | 120,000,000 |
| Grand Total | 207,100,000 |

Since the last figure is the distance from the earth, the total diameter of the universe is 414.2 million yojanas, not including the dimensions of the various heavenly bodies and *lokas*. The inclusion of these may be expected to bring this calculation in line with the figure of 500 million yojanas mentioned earlier.

Beyond the universe lies the limitless *Pradhāna*, that has within it countless other universes. Purāṇic cosmology views the universe as going through cycles of creation and destruction of 8.64 billion years.

### Reconciling Purāṇic and Standard Yojanas

It is clear that the Purāṇic yojana ($y_p$) is different from the Arthaśāstra yojana ($y_p$). To find the conversion factor, we equate the distances to the sun.

$$0.4375 \times 10^6\ y_s = 15.7 \times 10^6\ y_p \qquad (11.2)$$

In other words,

$$1\ y_s \approx 36\ y_p \qquad (11.3)$$

The diameter of the earth is now about $875 \times 36 \approx 31,500\ y_p$. This was taken to be 32,000 $y_p$, twice the size of Meru. This understanding is confirmed by the statements in the Purāṇas. For example, MP 126 says that the size of Bhāratavarṣa (India) is 9,000 $y_p$, which is roughly correct.

We conclude that the kernel of the Purāṇic system is consistent with the Siddhāntas. The misunderstanding of it arose because of their use of different units of distance.

## The Sun in the Universe

Now that we have a Purāṇic context, Sāyaṇa's statement on the speed of 2,202 yojanas per half-nimeṣa can be examined.

We cannot be absolutely certain what yojanas he had in mind: standard, or Purāṇic. But either way it is clear from the summary of Purāṇic cosmology that this speed could not be the speed of the sun. At the distance of 15.7 million yojanas, the sun's speed is only 121.78 yojanas ($y_p$) per half-nimeṣa. Or if we use the the figure from VaP, it is 116.67. Converted into the standard yojanas, this number is only 3.24 $y_s$ per half-nimeṣa.

Sāyaṇa's speed is about 18 times greater than the supposed speed of the sun in $y_p$ and $2 \times 18^2$ greater than the speed in $y_s$. So either way, a larger number with a definite relationship to the actual speed of the sun was chosen for the speed of light.

The Purāṇic size of the universe is 13 to 16 times greater than the orbit of the sun, not counting the actual sizes of the various heavenly bodies. Perhaps, the size was taken to be 18 times greater than the sun's orbit. It seems reasonable to assume, then, that if the radius of the universe was taken to be about 282 million yojanas, a speed was postulated for light so that it could circle the farthest path in the universe within one day. This served as the physical principle at the basis of the cosmology.

We saw that the astronomical numbers in the Purāṇas are much more consistent amongst themselves, and with the generally accepted sizes of the solar orbit, than was hitherto assumed. The Purāṇic geography must not be taken literally.

We also showed that the Sāyaṇa's figure of 2,202 yojanas per half-nimeṣa is consistent with Purāṇic cosmology where the size of "our universe" is a function of the speed of light. This size represents the space that can be spanned by light in one day.

The figure for speed was obtained either by this above argument, or by taking the postulated speed of the sun in the Purāṇas and multiplying that by 18, or by multiplying the speed in standard yojanas by $2 \times 18^2$. Since 18 is a sacred number in the Purāṇas, the fact that multiplication with this special number produced a figure that was in accord with the spanning of light in the universe in one day gave it special validation.

Is it possible that the number 2,202 arose because of a mistake of multiplication by 18 rather than a corresponding division (by 36) to reduce the sun speed to standard yojanas? The answer to that must be "no" because such an obvious mistake would have been easily discovered. Sāyaṇa's own brother Mādhava Vidyāraṇya was a distinguished astronomer and the incorrectness of this figure for the accepted speed of the sun would be obvious to him.

If Sāyaṇa's figure was derived from a postulated size of the universe, how was that huge size, so central to Indian thought, arrived at? A possible explanation is that the physical size of the universe was to parallel the estimates of its age. These age-estimates were made larger and larger to postulate a time when the heavenly bodies were in conjunction.

The great numbers of the Purāṇas suggest that the concepts of mahāyuga and kalpa, sometimes credited to the astronomers of the Siddhāntic period, have an old pedigree.

We provided a context in which Sāyaṇa's speed may be understood. In our explanation, the speed of light was taken to be $2 \times 18^2$ greater than the speed of the sun in standard yojanas so that light can travel the entire postulated size of the universe in one day. It is a lucky chance that the final number turned out to be equal to the true speed.

If we consider estimates of the unit of dhanus based on analysis of the dimensions of ancient monuments that are likely to have used round multiples of this basis length, it turns out to have a measure about 4 percent higher than 6 feet.[9] Use of this revised value would increase the speed of light value by 4 percent.

Some will claim that the probability of getting this number right is so low that it means that mind can obtain empirical knowledge by introspection alone. They would further claim that this is in accord with the assertions of scientists that they make their discoveries spontaneously, of which many accounts exist in the literature.[10] But as unique events that happened in the past, such accounts cannot be verified.

In the scientific field, Jacques Hadamard surveyed 100 leading mathematicians of his time, concluding many of them obtained entire solutions spontaneously. This list included the claim by the French mathematician Henri Poincaré that he arrived at the solution to a subtle mathematical problem as he was boarding a bus, and the discovery of the structure of benzene by Kekulé in a dream. More recently, the physicist Roger Penrose claimed to have found the solution to a mathematical problem while crossing a street.

Intuitive discovery must be common, and the reason why we don't hear of more such stories is because some people are unprepared to appreciate their intuition or translate it into meaningful narrative, and others feel uncomfortable speaking of their personal experience. It is also true that the creative intuition is not always correct, and the scientist's judgment is essential in separating the false solution from the true one.

Anomalous abilities and first person accounts of discovery that are spontaneous could either indicate that consciousness is more than a phenomenon based solely on matter or that these accounts are just a listing of coincidences. Conversely, there is no way to prove the veracity of the scientist's account of discovery. It is possible that the account is one that the scientist has come to believe over time and it does not correspond to fact.

The correctness of the speed of light figure may indicate an unknown connection between the speed of light and the cycles at the basis of Indian cosmology. In any event, the Indian speed of light is the most astonishing "blind hit" in the history of science!

# *12. Vedic and Babylonian Astronomy*

## Introduction

This chapter investigates possible connections between Vedic astronomy and Babylonian science. This is of importance for history of astronomy since Babylon is credited with careful observational astronomy in the wider ancient world.

It will be shown that key ideas in the Babylonian astronomy of 700 BCE are already present in the older Vedic texts. It will be established that the solar zodiac (rāśis) was used in Vedic India and a derivation of the symbols of the solar zodiac from the deities of the nakṣatras will be presented.

In view of the attested presence of the Indic people in the Mesopotamian region prior to 700 BCE, it is likely that if at all the two traditions influenced each other, the dependence is of the Babylonian on the Indian. It is of course quite possible that the Babylonian innovations emerged independent of the earlier Indic methods.

Indic presence in West Asia goes back to the second millennium BCE in the ruling elites of the Hittites and the Mitanni in Turkey and Syria, and the Kassites in Mesopotamia. The Hittite empire goes back to 18th century BCE and it reached its zenith in the 14th century BCE. The Kassites emerged as rulers of Babylon during 1600 to 1200 BCE.

The Mitanni were joined in marriage to the Egyptian pharaohs during the second half of the second millennium and they appear to have influenced that region as well.[1] The Ugaritic, known from writings found in the lost city of Ugarit in Syria, list 33 gods, just like the count of Vedic gods. The Ugaritic texts belong to the 14th through 12th century BCE. Greek accounts tell us that the Ugaritic believed in a cosmic egg out of which the earth emerged which is reminiscent of brahmāṇḍa of the Vedic view.

Although the Kassites vanished from the scene by the close of the second millennium, Indic groups remained in the general area for centuries, sustaining their culture by links through trade. Thus Sargon defeats one Bagdatti of Uišdiš in 716 BCE. The name Bagdatti (Skt. Bhagadatta) is Indic[2] and it cannot be Iranian because of the double 't'.

Pharaoh Akhenaten of Egypt was a son-in-law of Tushratta, the Mitanni king of North Syria, through queen Kiya. (The name Tushratta is spelled Tuišrata in the Hittite cuneiform script.) Some have suggested that the Sanskrit original is Daśaratha, others that it is Tveṣaratha (having splendid chariots), a name which is attested in the Ṛgveda. Letters exchanged between Akhenaten and Tushratta have been found in Amarna in Egypt and other evidence comes from the tombs of the period.

The Mitanni had Sanskrit names. The first Mitanni king was Sutarna I (good sun). He was followed by Baratarna I (*Paratarna*, great sun), Parauksṣatra (ruler with axe), Saustatar (*Saukṣatra*, son of Sukṣatra, the good ruler), Paratarna II, Artadāma (*Ṛtadhāman*, abiding in cosmic law), Sutarna II, Tushratta (*Daśaratha*), and finally Matiwazza (*Mativāja*, whose wealth is thought) during whose lifetime the Mitanni state appears to have become a vassal to Assyria.

The Mitanni ruled northern Mesopotamia out of their capital of Vasukhāni, "mine of wealth." Their warriors were called *marya*, which is proper Sanskrit. In a treaty between the Hittites and the Mitanni, Indic deities Mitra, Varuṇa, Indra, and Nāsatya (Aśvins) are invoked. A text by a Mitannian named Kikkuli uses words such as aika (*eka*, one), tera (*tri*, three), panza (*panca*, five), satta (*sapta*, seven), na (*nava*, nine), vartana (*vartana*, round). Another text has babru (*babhru*, brown), parita (*palita*, grey), and pinkara (*piṅgala*, red). Their chief festival was the celebration of viṣuva (solstice) very much like in India. It is not only the kings who had Sanskrit names.

The Indo-Aryan presence in West Asia persisted until the time of the Persian Kings like Darius and Xerxes. It is confirmed by the famous *daiva* inscription in which Xerxes (ruled 486-465 BCE) proclaims his suppression of the rebellion by the daiva worshipers of West Iran.

The Parsi religion is popularly called Zoroastrian after the Greek version of the name of the prophet Zarathushtra (zarat, like Sanskrit *harit*, golden; uṣṭra, Sanskrit or Old Persian for camel) who came from Bactria in northeast Iran, near Afghanistan. The scripture of the Zoroastrians is the Avesta. It includes the Yasna (Sanskrit *yajña*) with the Gāthās of Zarathushtra, Videvdat or Vendidad (Vi-daeva-dat, anti-Daeva), and Yasht (Skt. *yajat*, worship), which are hymns for worship. During the Sasanian period the Avesta was translated into Pahlavi and this version is the Zend Avesta.

It has been assumed for some time that the *daevas* of the Mazda faith are the same as the Vedic *devas* and therefore Zarathushtra inverted the *deva-asura* dichotomy of the Vedic period. In reality, the situation is more complex and the Vedic and the Zarathushtrian systems are much less different than is generally supposed.

The Vedic view of seeing the world in triple categories was later simplified in Purāṇic glosses into dichotomies like that of deva versus *asura* (including *rākṣasa*). Zarathusthra made a similar simplification using the dichotomy of *asura* (including *deva* as the *yazata*) and *daeva*.

The names that the Zoroastrians use for the gods are generally the same as the Vedic ones. For example, the three great Asuras of the Zoroastrians are: Ahura Mazda (*Asura Medha*), Mithra (*Mitra*), Baga (*Bhaga*). The common deities and seremonies are often identical, with the difference that the names have a Persian spelling as in Hvar and Khor instead of *Svar* for the Sun, Yima or Jam instead of Y*ama*, yasna or jashn instead of *yajña*, yazata instead of *yajata*, zaotar instead of *hota* (priest), and so on. Zarathushtra's Six immortals born of Amesha Spenta (Boundless Immortality):

- Vohu Manah (*Su Manah*): Good Intention; Persian Bahman
- Asha Vahishta (*Aśa Vasiṣṭha*): Best Law; Ardvahisht
- Kshathra Vairya (*Kṣatra Vairya*): Heroic Dominion
- Spenta Armaiti (*Spanda Aramati*): Bounteous Devotion
- Haurvatat (*Sarvatata*): Wholeness
- Amaratat (*Amaratata*): Immortality

The list of common deities and concepts make it clear that the Zoroastrian system is in harmony with Vedic cosmology. The presence of Indra in the list of the *daevas* mirrors the relegation of Indra in the Purāaṇic times where instead of connecting to *Svar* through the intermediate region of which Indra is lord, a direct worship of the Great Lord (Viṣṇu or Śiva) was stressed. This innovation is not counter to the Vedic system since the triple division is a recursive order. The devas are a part of the good forces in the Zoroastrian system as the *yazata* (the adored-ones). The Zoroastrian mythology remembers the Vedic sages and heroes such as Kavi Suśravah (Kay Khosrau), Kavi Uśanas (Kay Us).

Herodotus states that the "Persians built no temples, no altars, made no images or statues" (Herodotus 1.131-2). Arrian in the Indica (7) says that Indians "did not build temples for the gods." To the outsider also, the two religions of the Persians and the Indians looked similar.

The Sanskrit groups in West Asia most likely served as intermediaries for the transmission of ideas of Vedic astronomy to the Babylonians in West Asia. Since we see a gap of several centuries in the adoption of specific ideas, one can fix the direction of transmission.

## Western Histories of Indian Astronomy

The early Western studies of Indian texts duly noted the astronomical references to early epochs going back to three or four thousand BCE. As the Indian astronomical texts were studied it was discovered that the Indian methods were different from those used in other civilizations. The French astronomer M. Jean Sylvain Bailly in his classic *Traité de l'Astronomie Indienne et Orientale* (1787) described the methods of the Sūrya Siddhānta and other texts and expressed his view that Indian astronomy was very ancient. Struck by the elegance and simplicity of its rules and its archaic features, Bailly believed that astronomy had originated in India and it was later transmitted to the Chaldeans in Babylon and to the Greeks.

As against this, John Bentley in 1799 in a study in the *Asiatick Researches* suggested that the parameters of the Sūrya Siddhānta were correct for 1091 CE. But Bentley was criticized for failing to notice that the Sūrya Siddhānta had been revised using bīja corrections,[3] and therefore his arguments did not negate the central thesis of Bailly.

In the next several decades Indian astronomy became a contested subject. Part of the difficulty arose from a misunderstanding of the Indian system due to the unfamiliar structure of its luni-solar system. Later, it became a hostage to the idea that the Vedic people had come as invaders to India around 1500 BCE,[4] and that Indians were otherworldly and uninterested in science and they lacked the tradition of observational astronomy until medieval times.[5]

It was argued that astronomical references in the texts either belonged to recent undatable layers or were late interpolations.[6] Conversely, Ebenezer Burgess maintained that the evidence, although not conclusive, pointed to the Indians being the original inventors or discoverers of:[7] (i) the lunar and solar divisions of the zodiac, (ii) the primitive theory of epicycles, (iii) astrology, and (iv) names of the planets after gods.[8]

With the decipherment of the Babylonian astronomical tablets, it was thought that early Indian astronomy may represent lost Babylonian or Greek inspired systems.[9] But this leads to many difficulties, anticipated more than a hundred years earlier by Burgess, including the *incongruity* of the epochs involved. This is possible only if one were to lump all Indian texts that are prior to 500 BCE into a mass of uniform material.[10]

Śaṅkara Bālakṣṇa Dīkṣita's *Bhāratīya Jyotiṣa*,[11] published in the closing years of the 19th century, contained enough arguments against looking for any foreign basis to the Vedāṅga Jyotiṣa, but this question was reopened in the 1960s.[12] The basis behind the rearticulation of an already disproved theory was the idea that "the origin of mathematical astronomy in India [is] just one element in a general transmission of Mesopotamian-Iranian cultural forms to northern India during the two centuries that antedated Alexander's conquest of the Achaemenid empire."[13]

Overwhelming evidence has since been furnished that disproves this theory,[14] but many people remain confused about the relationship between the two astronomy traditions. The idea that India did not have a tradition of observational astronomy was refuted convincingly by Roger Billard more than thirty years ago. In his book,[15] he showed that the parameters used in the various siddhāntas actually belonged to the period at which they were created giving lie to the notion that they were based on some old tables transmitted from Mesopotamia or Greece. The distinguished historian of astronomy B.L. van der Waerden reviewed the ensuing controversy in a 1980 paper titled *Two treatises on Indian astronomy* where he evaluated the views of Billard and his opponent Pingree. He ruled thus:[16]

> Billard's methods are sound, and his results shed new light on the chronology of Indian astronomical treatises and the accuracy of the underlying observations. We have also seen that Pingree's chronology is wrong in several cases. In one case, his error amounts to 500

years.

For the pre-Siddhāntic period, the discovery of the astronomy of the Ṛgveda[17]establishes that the Indians were making careful observations in the Vedic period.

One might ask why should one even bother to revisit Pingree's thesis if it stands discredited. The reason to do so is that it provides a good context to compare Babylonian and Indian astronomy and examine their similarities and differences. It also provides a lesson in how bad method will lead to incongruous conclusions.

It is not my intention to replace Babylon by India as the source of astronomical knowledge. I believe that the idea of development in isolation is simplistic; there existed much interaction between ancient civilizations. I also believe that the borrowing in the ancient world was at best of the general notions and the details of the astronomical systems that arose had features which made each system unique. Rather than assign innovation to any specific group, we may speak of regions in which, due to a variety of social, economic, and cultural reasons, new ways of looking at the universe arose. Thus, we cannot ignore the pre-Babylonian Indian literature just as we must not ignore the fact that in the mid-first millennium BCE the Babylonians embarked on a notable period of careful astronomical records and the use of mathematical models.[18]

The next section will introduce pre-Vedāṅga Jyotiṣa Indian astronomy which will be followed by an account of Babylonian astronomy so that the question of the relationship between Vedāṅga Jyotiṣa and Babylonian astronomy is understood. Since the pre-Vedāṅga material belongs mainly to the Saṃhitās that are squarely in the second millennium BCE or earlier, it could not have been influenced by Babylonian astronomy. We will also use the evidence from the Brāhmaṇas which antedate the Babylonian material in the most conservative chronology.

Once we have understood the nature of this earlier astronomy, we will relate it to the Vedāṅga Jyotiṣa and Babylonian astronomy.

## Pre-Vedāṅga Jyotiṣa Astronomy

The facts that emerge from the pre-Vedāṅga material include: knowledge of the duration of the year, concept of the tithi, naming of ecliptic segments after gods, knowledge of solstices for ritual, the 27- and 12- segment divisions of the ecliptic, and the motions of the sun and the moon.

There were several traditions within the Vedic system. For example, the month was reckoned in one with the new moon, in another with the full moon, or there existed both the six-day and seven-day weeks, or the motion of the sun was viewed both with respect to the 12 Ādityas and 27 nakṣatras.

## Identification of the Nakṣatras

The cycle of the Nakṣatras, asterisms or segments of the ecliptic with which the moon is conjoined on successive nights in its passage around the earth, is $27\frac{1}{3}$ days. Because of this extra one-third day, there is drift in the conjunctions. Also, the fact that the lunar year is shorter than the solar year by over 11 days implies a further drift through the nakṣatras that is corrected by the use of intercalary months.

The earliest lists of nakṣatras in the Vedic books begin with Kṛttikās, the Pleiades; much later lists dating from sixth century CE begin with Aśvinī when the vernal equinox occurred on the border of Revatī and Aśvinī. It was assumed that the beginning of the list marked some astronomical in the third millennium BCE. But such knowledge could not have arisen suddenly and there must have been a large body of astronomical lore, going back centuries if not millennia, upon which the nakśatra system was grafted.

Each nakṣatra has a presiding deity (Taittirīya Saṃhitā 4.4.10). In the Vedāṅga Jyotiṣa, the names of the nakṣatra and the deity are used interchangeably. It seems reasonable to assume that such usage had sanction of the tradition. The deities associated with the nakśatras are central to Vedic mythology, confirming that astronomy, and the corresponding maps of the internal sky, provides the key to its understanding.

Table 12.1 provides a list of the nakṣatras, the presiding deities, and the approximate epoch for the winter and summer solstice for a few selected nakṣatras that are relevant to this paper. It is noteworthy that the earliest Vedic texts provide us statements that recognize the movement of the solstices into new nakṣatras, giving us means to find approximate dates for these texts. Our identification of the nakṣatras has improved thanks to the work of Narahari Achar[19] who has used simulation software for sky maps that allows us to see the stars and the planets in the sky as the Vedic people saw them. Using this tool he has shown that some previous identifications made without a proper allowance for the shift in the ecliptic due to precession be modified.

The nakṣatras in the Vedāṅga Jyotiṣa represent 27 *equal parts* of the ecliptic. This is an old tradition since the Saṃhitās (Kāṭhaka and Taittirīya) mention explicitly that Soma is wedded to all the nakṣatras and spends equal time with each. The stars of the nakṣatras are a guide to determine the division of the ecliptic into equal parts. Each nakṣatra corresponds to $13\frac{1}{3}$ degrees.

The following is a list of the nakṣatras and their locations:

1. **Kṛttikā**, from the root *kṛt*, 'to cut.' These are the Pleiades, $\eta$ Tauri. *Deity:* Agni

2. **Rohiṇī**, 'ruddy,' is $\alpha$ Tauri, Aldebaran. *Deity:* Prajāpati

3. **Mṛgaśīrṣa**, 'Deer's head,' $\beta$ Tauri. *Deity:* Soma

4. **Ārdrā**, 'moist,' is $\gamma$ Geminorum. (Previously it was thought to be Betelgeuse, $\alpha$ Orionis.) *Deity:* Rudra

5. **Punarvasū**, 'who give wealth again,' is the star Pollux, or $\beta$ Geminorum. *Deity:* Aditi

6. **Tiṣya**, 'pleased,' or **Puṣya**, 'flowered,' refers to $\delta$ Cancri in the middle of the other stars of this constellation. *Deity:* Bṛhaspati

7. **Āśreṣā** or **Āśleṣā**, 'embracer,' represents $\delta, \epsilon, \zeta$ Hydrae. *Deity:* Sarpāḥ

8. **Maghā**, 'the bounties,' is the group of stars near Regulus, or $\alpha, \eta, \gamma, \zeta, \mu, \epsilon$ Leonis. *Deity:* Pitaraḥ

9. **Pūrvā Phālgunī**, 'bright,' $\delta$ and $\theta$ Leonis. *Deity:* Aryaman (Bhaga)

10. **Uttarā Phālgunī**, 'bright,' $\beta$ and 93 Leonis. *Deity:* Bhaga (Aryaman)

11. **Hasta**, 'hand.' The correct identification is $\gamma$ Virginis. (Previously, the stars $\delta$, $\gamma$, $\epsilon$, $\alpha$, $\beta$ in Corvus were assumed, but they are very far from the ecliptic and thus not correctly located for this nakṣatra.) *Deity:* Savitar

12. **Citrā**, 'bright.' This is Spica or $\alpha$ Virginis. *Deity:* Indra (Tvaṣṭṛ)

13. **Svātī**, 'self-bound,' or **Niṣṭyā**, is $\pi$ Hydrae. (The previous identification of Arctutus or $\alpha$ Bootis is too far from the ecliptic.) *Deity:* Vāyu

14. **Viśākhā**, 'without branches.' The stars $\alpha_2$, $\beta, \sigma$ Librae. *Deity:* Indrāgni

15. **Anurādhā**, 'propitious,' 'what follows Rādhā.' These are the $\beta, \delta, \pi$ Scorpii. *Deity:* Mitra

16. **Rohiṇī**, 'ruddy', or **Jyeṣṭhā**, 'eldest.' This is Antares, $\alpha$ Scorpii. *Deity:* Indra (Varuṇa)

17. **Vicṛtau**, 'the two releasers,' or **Mūla**, 'root.' These are the stars from $\epsilon$ to $\lambda, \nu$ Scorpii. *Deity:* Pitaraḥ (Nirṛti)

18. **Pūrvā Āṣāḍhā**, 'unconquered,' $\delta, \epsilon$ Sagittarii. *Deity:* Āpaḥ

19. **Uttarā Āṣāḍhā**, 'unconquered,' $\sigma, \zeta$ Sagittarii. *Deity:* Viśve devaḥ

    **Abhijit**, 'reaching victory.' The name refers to a satisfactory completion of the system of nakṣatras. The star is Vega, the brilliant $\alpha$ Lyrae. This is the star that does not occur in the lists which have only 27 nakṣatras on it. *Deity:* Brahmā

20. **Śroṇā**, 'lame,' or **Śravaṇa**, 'ear,' $\beta$ Capricornus. (This is in place of Altair, $\alpha$ Aquillae.) *Deity:* Viṣṇu

21. **Śraviṣṭhā**, 'most famous.' Achar argues that it should be $\delta$ Capricornus rather than the previously thought $\beta$ Delphini. It was later called **Dhaniṣṭhā**, 'most wealthy.' *Deity:* Vasavaḥ

22. **Śatabhiṣaj**, 'having a hundred physicians' is $\lambda$ Aquarii and the stars around it. *Deity:* Indra (Varuṇa)

23. **Proṣṭhapadā**, 'feet of stool,' are the stars near $\alpha$ Pegasi. *Deity:* Aja Ekapād

24. **Uttare Proṣṭhapadā**, 'feet of stool,' and later **Bhadrapadā**, 'auspicious feet.' These are $\gamma$ Pegasi and other nearby stars. *Deity:* Ahirbudhnya

25. **Revatī**, 'wealthy,' $\eta$ Piscium. *Deity:* Pūṣan

26. **Aśvayujau**, 'the two horse-harnessers,' are the stars $\beta$ and $\alpha$ Arietis. **Aśvinī** is a later name. *Deity:* Aśvinau

27. **Apabharaṇī**, 'the bearers,' are the group around $\delta$ Arietis. *Deity:* Yama

The antiquity of the nakṣatra system becomes clear when it is recognized that all the deity names occur in RV 5.51 (this insight is due to Narahari Achar[20]). This hymn by Svastyātreya Ātreya lists the deity names as:

> Aśvin, Bhaga, Aditi, Pūṣan, Vāyu, Soma, Bṛhaspati, SARVAGAṆAḤ, Viśve Devaḥ, Agni, Rudra, Mitra, Varuṇa, Indrāgni.

The sarvagaṇaḥ are the gaṇaḥ (groups) that include the Vasavaḥ, Pitaraḥ, Sarpaḥ (including Ahi and Aja), Āpaḥ, and the Ādityagaṇaḥ (Dakṣa Prajāpati, Aryaman, Viṣṇu, Yama, Indra). There is no doubt that the ecliptic is meant because the last verse of the hymn refers explicitly to the fidelity with which the sun and the moon move on their path, the ecliptic.

The division of the circle into 360 parts or 720 parts was also viewed from the point of view the nakṣatras by assigning 27 upanakṣatras to each nakṣatra (Śatapatha Br. 10.5.4.5). This constituted an excellent approximation because $27 \times 27 = 729$. In other words, imagining each nakṣatra to be further divided into 27 equal parts made it possible to conceptualize half a degree when examining the sky.

The identification of the nakṣatras is in consistent with their division into the two classes of *deva* and *yama* nakṣatras as in the Taittirīya Brāhmaṇa 1.5.2.7:

> *kṛttikāḥ prathamaṃ viśākhe uttamaṃ tāni devanakṣatrāṇi anurādhāḥ prathamaṃ apabharaṇihyuttamaṃ tāni yama -nakṣatrāṇi yāni devanakṣatrāṇi tāni dakṣiṇena pariyanti yāni yamanakṣatrāṇi tānyuttarāṇi iti.*

> Kṛttikās are the first and Viśākhe are the last; those are *deva* nakṣatras. Anurādhās are the first and Apabharaṇī is the last; those are the *yama* nakṣatras. The deva nakṣatras revolve from the south; the yama nakṣatras revolve from the north.

Kṛttikās to Viśākhe are the *deva* nakṣatras because they lie north of the equator, whereas the others are *yama* nakṣatras because they lie south of the equator. Since the devas are supposed to live in the north pole and Yama in the south pole, the deva nakṣatras revolve south of the abode of the devas, and the yama nakṣatras revolve north of the abode of Yama. This classification helps confirm the identification of the nakṣatras.

Abhijit, which comes between the nineteenth and the twentieth in the above list, does not occur in the list of the 27 in the Taittirīya Saṃhitā or in the Vedāṅga Jyotiṣa. The Maitrāyāṇī and Kāṭhaka Saṃhitās and the Atharvaveda contain lists with the 28 nakṣatras.

When the asterisms Kṛttikā and Viśākhā defined the spring and the autumn equinoxes, the asterisms Maghā and Śraviṣṭhā defined the summer and the winter solstices.

### The Solstices

There were two kinds of year in use. In one, the year was measured from one winter solstice to another; in the other, it was measured from one vernal equinox to another. Obviously, these years were solar and related to the seasons (tropical).

The wheel of time was defined to have a period of 360 parts. This number seems to have been chosen as the average of 354 days of the lunar year and the 366 days for the solar year.

In TS 6.5.3, it is said that the sun travels moves northward for six months and southward for six months. The Brāhmaṇas speak of ritual that follows the course of the year starting with the winter solstice. For example, the Pañcaviṃśa Brāhmaṇa describes sattras of periods of several days, as well as one year (PB 25.1), 12 years, 1000 days, and 100 years. In these types of ritual the number of days were recorded, providing a means of determining an accurate size of the solar year. The sattra of 100 years appears to refer to the centennial system of the Saptarṣi calendar.

*Table 12.1:* Nakṣatras with their deity names and the approximate epoch of winter solstice and spring equinox at the midpoint of each segment

| | *Nakṣatra* | *Deity* | *W. Solstice* | *S. Equinox* |
|---|---|---|---|---|
| 1 | Kṛttikā | Agni | | 2000 BCE |
| 2 | Rohiṇī | Prajāpati | | 3000 BCE |
| 3 | Mṛgaśīrṣa | Soma | | 4000 BCE |
| 4 | Ārdrā | Rudra | | 5000 BCE |
| 5 | Punarvasū | Aditi | | 6000 BCE |
| 6 | Tiṣya or Puṣya | Bṛhaspati | | |
| 7 | Āśreṣā or Āśleṣā | Sarpāḥ | | |
| 8 | Maghā | Pitaraḥ | | |
| 9 | Pūrvā Phālgunī | Aryaman | | |
| 10 | Uttarā Phālgunī | Bhaga | | |
| 11 | Hasta | Savitar | | |
| 12 | Citrā | Indra | | |
| 13 | Svātī/ Niṣṭyā | Vāyu | | |
| 14 | Viśākhā | Indrāgni | | |
| 15 | Anurādhā | Mitra | | |
| 16 | Rohiṇī | Indra | | |
| 17 | Vicṛtau or Mūla | Pitaraḥ | 2000 CE | |
| 18 | Pūrvā Āṣāḍhā | Āpaḥ | 1000 CE | |
| 19 | Uttarā Āṣāḍhā | Viśve devaḥ | 0 CE | |
| * | Abhijit | Brahmā | | |
| 20 | Śroṇā/Śravaṇa | Viṣṇu | 1000 BCE | |
| 21 | Śraviṣṭhā/Dhan. | Vasavaḥ | 2000 BCE | |
| 22 | Śatabhiṣaj | Indra | 3000 BCE | |
| 23 | Proṣṭhapadā | Aja Ekapād | 4000 BCE | |
| 24 | Uttare Proṣṭha. | Ahirbudh. | 5000 BCE | 2000 CE |
| 25 | Revatī | Pūṣan | 6000 BCE | 1000 CE |
| 26 | Aśvayujau | Aśvinau | 7000 BCE | 0 CE |
| 27 | Apabharaṇī | Yama | | 1000 BCE |

The solstice day was probably determined by the noon-shadow of a vertical pole. The Aitareya Brahmana speaks of the sun remaining stationary for about 21 days at its furthest point in the north (summer solstice) and likewise for its furthest point in the south (winter solstice). This indicates that the motion of the sun was not taken to be uniform all the time.

## Months

The year was divided into 12 months which were defined with respect to the nakṣatras, and with respect to the movements of the moon.

The Taittirīya Saṃhitā (TS) (4.4.11) gives a list of solar months:

> Madhu, Mādhava (Vasanta, Spring), Śukra, Śuci (Grīṣma, Summer), Nabha, Nabhasya (Varṣā, Rains), Iṣa and Ūrja (Śarad, autumn), Sahas and Sahasya (Hemanta, Winter), and Tapa and Tapasya (Śiśir, Deep Winter).

The listing of months by the season implies that parts of the ecliptic were associated with these 12 months and they are also known by their Āditya names (Table 12.2). These names vary from text to text, therefore, we are speaking of more than one tradition. It should be noted that different lists of names need not mean usage at different times.

Now we investigate if the rāśi names associated with the segments were a part of the Vedic tradition or if they were adopted later. In any adoption from Babylonia or Greece, one would not expect a fundamental continuity with the nakṣatra system. Taking the clue from the Vedāṅga Jyotiṣa, where the names of the nakṣatras and the deities are used interchangeably, we will investigate if the rāśi names are associated with the segment deities.

The nakṣatra names of the months each cover $30^o$ of the arc, as against the $13\frac{1}{3}^o$ of the lunar nakṣatra segment. Therefore, the extension of each month may stretch over upto three nakṣatras with corresponding deities. This will be seen in Figure 12.1 or in the list of Figure 12.2.

The choice made in Figure 12.1, where Vaiśākha begins with the the sun in the ending segment of Aśvinī and the moon at the mid-point of Svātī is the most likely assignment as it bunches the Āśāḍhās and the Phālgunīs in the right months, with the Proṣṭhapadās three-fourths correct and Śroṇā half-correct. The full-moon day of the lunar month will thus fall into the correct nakṣatra. Since the solar and the lunar months are not in synchrony, the mapping would tend to slip upto two nakṣatra signs until it is corrected by the use of the intercalary month. At worst, we get a sequence of rāśis which is out of step by one.

*Table 12.2:* The twelve months with the nakṣatra named after and Ādityas names (from Viṣṇu Purāṇa)

| *Month* | *Nakṣatra* | *Āditya* |
|---|---|---|
| Caitra | Citrā | Viṣṇu |
| Vaiśākha | Viśākhā | Aryaman |
| Jyaiṣṭha | Jyeṣṭhā | Vivasvant |
| Āśāḍha | Āśāḍhās | Aṃśu |
| Śrāvaṇa | Śroṇa | Parjanya |
| Bhādrapada | Proṣṭhapadas | Varuṇa |
| Āśvayuja | Aśvinī | Indra |
| Kārtika | Kṛttikā | Dhātṛ |
| Mārgaśīrṣa | Mṛgaśiras | Mitra |
| Pauṣa | Tiṣya | Pūṣan |
| Māgha | Maghā | Bhaga |
| Phālguna | Phālgunī | Tvaṣṭā |

We present now the basis to our identification of the names of the nakṣatras from the Ṛgveda:

Vaiśākha = Svātī to Anurādhā = Vāyu, Indrāgni, Mitra
= Vṛṣa, Bull for Indra, e.g. RV 8.33; also Vāyu is sometimes identified with Indra and the two together called Indravāyū, and Vāyu is also associated with cow (RV 1.134)

Jyaiṣṭha = Anurādhā to Mūla = Mitra, Varuṇa, Pitaraḥ
= Mithuna, Gemini, from the cosmic embrace of Mitra and Varuṇa

Āśāḍha = Pūrva Āśāḍhā to Śroṇa = Āpaḥ, Viśve Devaḥ, Viṣṇu
= Karka, circle or Cancer, the sign of Viṣṇu's cakra (e.g. RV 1.155.6)

Śrāvaṇa = Śroṇa to Śatabhiṣaj = Viṣṇu, Vasavaḥ, Indra
= Siṃha, Lion, after Indra as in RV 4.16.14

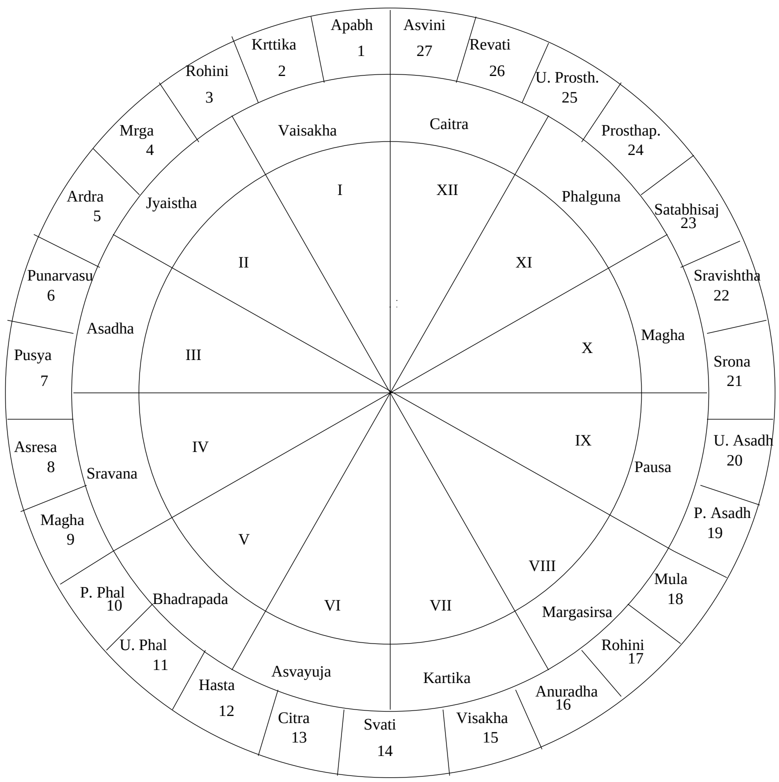



Figure 12.1: The 27-fold and 12-fold division of the ecliptic. The first rāśi is Vṛṣa with the corresponding month of Vaiśākha

Bhādrapada = Śatabhiṣaj to U. Proṣṭhapada = Indra, Aja Ekapāda, Ahirbudhnya
= Kanyā, Virgin, apparently from Aryaman in the opposite side of the zodiac who is the wooer of maidens, kanyā (RV 5.3.2)

Āśvina = U. Proṣṭhapada to Aśvayujau = Ahirbudhnya, Pūṣan, Aśvayujau
= Tulā, Libra, from the Āśvins who denote balance of pairs (e.g. RV 2.39, 5.78, 8.35)

Kārtika = Apabharaṇī to Rohiṇī = Yama, Agni, Prajāpati
= Ali (Vṛścika), Scorpion, from Kṛttika, to cut

Mārgaśīrṣa = Rohiṇī to Ārdrā = Prajāpati, Soma, Rudra
= Dhanuṣ, Archer, from the cosmic archer Rudra (RV 2.33, 5.42, 10.125)

Pauṣa = Ārdrā to Puṣya = Rudra, Aditi, Bṛhaspati
= Makara, Goat, Rudra placing goat-head on Prajāpati, and goat is the main animal sacrificed at the ritual of which Bṛhaspati is the priest

Māgha = Puṣya to Maghā = Bṛhaspati, Sarpaḥ, Pitaraḥ
= Kumbha, Water-bearer, from the water-pot offerings to the pitaraḥ

Phālguna = Phālgunīs to Hastā = Aryaman, Bhaga, Savitar
= Mīna, Fish, representing Bhaga (alluded to in RV 10.68)

Caitra = Hastā to Svātī = Savitar, Indra, Vāyu
= Meṣa, Ram, from Indra, see, e.g., RV 1.51

We observe that for most solar zodiac segments a plausible name emerges from the name of the deity. The choice of the symbols was also governed by another constraint. The Brāhmaṇa texts call the year as the sacrifice and associate different animals with it.[21] In the short sequence, these animals are goat, sheep, bull, horse, and man. Beginning with the goat-dragon at number 9 in the sequence starting with Vaiśākha, we have sheep at 12, bull at 1, horse (also another name for the sun in India) as the sun-disk at 3, and man as archer at 8.

**Intercalation**

The system of intercalation of months (adhikamāsa) was used to bring the lunar year in synchrony with the solar year over a period of five years.

The use of the intercalary month (adhikamāsa) goes back to the Ṛgveda itself:

> *vedamāso dhṛtavrato dvādaśa prajāvataḥ*
> *vedā ya upajāyate* (RV 1.25.8)

> Dhṛtavrata (Varuṇa) knew the twelve productive months;
> he also knew about the thirteenth additional month.

In the Atharvaveda (13.3.8), it is said:

> *ahorātraivimitaṃ triṃśadaṅgaṃ*
> *trayodaṣaṃ māsaṃ yo nirmimīte* (AV 13.3.8)

> He who forms the thirteenth month containing thirty
> days and nights.

The names of the two intercalary months are given as *saṃsarpa* and *aṃhaspati* in the Taittirīya Saṃhitā 1.4.14.

There are several other similar references in the Saṃhitā literature to the various intercalary schems that were used to reconcile the lunar and solar years.

The Ṛgveda mentions yuga in what is most likely a five-year sense in RV 1.158.6. The names of two of these five years, *saṃvatsara* and *parivatsara* are found in RV 7.103.7. The Vājasaneyi Saṃhitā (27.45 and 30.16) and the Taittirīya Saṃhitā (5.5.7.1-3) give the names of all the five years. These names are: saṃvatsara, parivatsara, idāvatvara, iduvatsara, and vatsara.

The number five is fundamental to Vedic imagination. Thus there are five-layers of the altar, five breaths within man, five seasons, and five kinds of sacrifices. It was natural then to conceive of a five-year yuga as a basic period within a system of larger yugas.

The use of the five year yuga is natural to do a basic synchronization of the lunar and the solar years. Longer periods are required for a more precise synchronization rules.

### Circle of 360$^o$

In Ṛgveda 1.164.11, mention is made of the 720 paired sons of the wheel of time which has twelve spokes. These 720 pairs are the 720 days and nights of the civil year. In RV 1.164.48 we are explicitly told of the 360 parts of the wheel of time.

> *dvādaśa pradhayaś cakram ekaṃ*
> *trīṇi nabhyāni ka utacciketa*
> *tasmin sākaṃ triśatā na śaṅkavo*
> *arpitāḥ ṣaṣṭirna calācalāsaḥ* (RV 1.164.48)
>
> Twelve spokes, one wheel, three navels, who can comprehend this? In this there are 360 spokes put in like pegs which do not get loosened.

This means that the ecliptic, which is the wheel of time, is divided into 360 parts. Each of these parts is what is now known as a degree. The three navels appear to be the three different kinds of divisions of it: solar and lunar segments and days.

The division of the circle into four quadrants of 90 degrees each is described in another hymn:

> *caturbhiḥ sākṃ navatiṃ ca nāmabhiś cakraṃ na vṛttaṃ*
> *vyatī̄ḍr avīvipat* (RV 1.155.6)
>
> He, like a rounded wheel, hath in swift motion set his ninety racing steeds together with the four.

The division of the wheel of time into 360 parts occurs elsewhere as well. In Śatapatha Br. 10.5.4.4, it is stated that "360 regions encircle the sun on all sides."

The division into half a degree is very easy to identify in the sky. The radial size of the sun or moon is slightly more than this angular size, being exactly 60/113 degrees.

Note, further, that the day is divided into 60 nāḍikas in the Vedāṅga Jyotiṣa. Since the day is to the year what the degree is to the circle, this means that the degree was further divided into 60 parts.

The number 360 also represents the equivalence between time and the subject. In the Āyurveda, the number of bones of the developing fetus are taken to be 360, which fuse into the 206 bones of the adult.

### Various Divisions of the Ecliptic

It may be argued that because the original list of 27 nakṣatras contains only 24 distinct names, these represent the 24 half months of the year. Later, to incorporate lunar conjunctions, the segments were expanded to describe the motions of the moon.

In the Ṛgveda (2.27), six Ādityas are listed which appear to be segments corresponding to the six seasons. The names given are: Mitra, Aryaman, Bhaga, Varuṇa, Dakṣa, Aṃśa.

This notion is supported by the fact that the ecliptic is also described in terms of the twelve Ādityas as in Table 12.3. In the Śatapatha Brāhmaṇa (6.1.2.8), Prajāpati is said to have "created the twelve Ādityas, and placed them in the sky." In Śatapatha Br. (11.6.3.8), it is stated that the Ādityas are the twelve months (*dvādaśa māsaḥ*). This means clearly a twelve part division of the circuit of the sun.

The correspondence between the 27-fold division and the 12-fold division of the ecliptic may be seen in Figure 12.1.

Further division of the ecliptic is seen in the subdivision of each of the rāśis into 2, 3, 4, 7, 9, 10, 12, 16, 20, 24, 27, 30, 40, 45, 45, and 60 parts.

## Babylonian Astronomy

Our knowledge of Babylonian astronomy comes from three kinds of texts. In the first class are: (i) astronomical omens in the style of *Enūma Anu Enlil* ("when the gods Anu and Enlil") that go back to the second millennium BCE in a series of 70 tablets; (ii) the two younger Mul Apin tablets which is more astronomical; (iii) royal reports on omens from 700 BCE onwards.

The second class has astronomical diaries with excellent observations over the period 750 BCE to 75 CE. The third class has texts from the archives in Babylon and Uruk from the period of the last four or five centuries BCE which deal with mathematical astronomy.

In late texts the ecliptic is divided into 12 zodiacal signs, each of length precisely 30 degrees. Aaboe has proposed[22]that the replacement of constellations by $30^o$ segments took place in the fifth century BCE

Babylonian mathematics is sexagesimal, that is, it uses a place-value system of base 60. This is considered one of the characteristic features of the Babylonian mathematical tradition.

The Babylonian year began with or after vernal equinox. The calendar is lunar with a new month beginning on the evening when the crescent of the new moon becomes visible for the first time. A month contains either 29 days (hollow) or 30 days (full). Since 12 lunar months add up to only 354 days, an intercalary month was occasionally introduced. Starting mid-fifth century, the intercalations followed the Metonic cycle where every group of 19 years contained seven years with intercalary months.

In the late texts the ecliptic is divided into 12 zodiacal signs, each of length precisely 30 degrees (uš). The first list of stars which used the signs of the zodiac is dated to about 410 BCE

The zodiacal signs have much overlap with the Indian ones, but they appear from nowhere. We cannot, for example, understand the basis of goat-fish, whereas the goad-headed Prajāpati is one of the central stories in Vedic lore. These signs do not belong to the same type. They include furrow, hired hand, and star. They could not have served as the model for the Indian zodiacal names or the Greek ones because of their haphazard nature. On the other hand, they could represent memory of an imperfectly communicated Indian tradition which was adapted into the Babylonian system. The Indic kingdoms in West Asia in the second millennium BCE could have served as the intermediaries in such transmission.

The Babylonians had two systems to place the signs on the ecliptic. In one, the summer solstice was at $8^o$ in kušu (and the winter solstice in $8^o$ in máš); in another system, the solstices were at $10^o$ of their signs. They measured the moon and the planets from the ecliptic using a measure called *she*, equal to 1/72 of a degree. They appear to have used two models for the sun's motion. In one, the sun's velocity changes suddenly; in another, it goes through a zig-sag change.

As far as planets are concerned, they calculated the dates of the instants the planet starts and ends its retrogression, the first visible heliacal rising, the last visible heliacal rising, and opposition. They also computed the position of the planet on the ecliptic at these instants. In the planetary theory, the synodic month is divided into 30 parts, which we now call *tithi* from its Indian usage.

*Table 12.3*: The Zodiac signs

| *Latin* | *Babylonian* | *Greek* |
|---|---|---|
| Aries | hun, lu (hired hand) | Krios (ram) |
| Taurus | múl (star) | Tauros (bull) |
| Gemini | mash-mash (twins) | Didymoi (twins) |
| Cancer | alla$_x$, kušu (?) | Karkinos (crab) |
| Leo | a (lion) | Leon (lion) |
| Virgo | absin (furrow) | Parthenos (virgin) |
| Libra | rín (balance) | Khelai (claws) |
| Scorpio | gír (scorpion) | Skorpios (scorpion) |
| Sagittarius | pa (name of a god) | Toxotes (archer) |
| Capricornus | máš (goat-fish) | Aigokeros (goat-horned) |
| Aquarius | gu (?) | Hydrokhoos (water) |
| Pisces | zib, zib-me (tails) | Ikhthyes (fishes) |

In the Babylonian planetary models the concern is to compute the time and place of first stationary points. Two different theories to do this were proposed which have been reconstructed in recent decades.[23]

## Babylonian Astronomy and the Jyotiṣa

The thesis that Babylonian astronomy led to Vedic astronomy was summarized in the following manner by David Pingree:[24]

> Babylonian astronomers were capable of devising intercalation-cycles in the seventh, sixth, and fifth centuries B.C., and there is evidence both in the Greek and in the cuneiform sources that they actually did so; and by the early fourth century B.C. they had certainly adopted the quite-accurate nineteen-year cycle. It is my suggestion that some knowledge of these attempts reached India, along with the specific astronomical material in the fifth or fourth century B.C. through Iranian intermediaries, whose influence is probably discernible in the year-length selected by Lagadha for the *Jyotiṣavedāṅga*.

> But the actual length of the yuga, five years, was presumably accepted by Lagadha because of its identity with a Vedic lustrum. Not having access to a series of extensive observations such as were available to the Babylonians, he probably was not completely aware of the crudeness of his system. And the acceptance of this cycle by Indians for a period of six or seven centuries or even more demonstrates among other things that they were not interested in performing the simplest acts of observational astronomy.

The specific items from Babylonian astronomy that Pingree believes were incorporated into the "later" Vedic astronomy are:

1. The ratio of 3:2 for the longest to the shortest day used after 700 BCE.

2. The use of a linear function to determine the length of daylight in intermediate months.

3. The use of the water-clock.

4. The concept of the *tithi* as the thirtieth part of the lunar month.

5. The use of two intercalary months in a period of 5 years.

6. The concept of a five-year yuga.

**Length of the Day**

The proportion of 3:2 for the longest to the shortest day is correct for northwest India. On the other hand, the Babylonians until 700 BCE or so used the incorrect proportion of 2:1. It is clear then that the Babylonians for a long time used a parameter which was completely incorrect. They must have, therefore, revised this parameter under the impulse of some outside influence.

In any event, the 3:2 proportion proves nothing because it is correct both for parts of India and Babylon. Its late usage in Babylonia points to the limitations of Babylonian observational astronomy before 700 BCE

### The Use of a Linear Function for Length of Day

The interpolation formula in the Ṛgjyotiṣa, verse 7, is:

$$d(x) = 12 + 2x/61$$

where $d$ is the duration of day time in muhūrtas and $x$ is the number of days that have elapsed since the winter solstice.

The use of this equation is natural when one considers the fact that the number of muhūrtas required for the winter solstice for the 3:2 proportion to hold is 12. This ensures that the length of day and night will be equal to 15 muhūrtas each at the equinox.

The Taittirīya Saṃhitā 6.5.3.4 speaks clearly of the northern and southern movements of the sun: *ādityaḥṣaṇmāso dakṣiṇenaiti ṣaḍuttareṇa*.

The Brāhmaṇas count days starting from the winter solstice and the period assumed between the two solstices is 183 days. It is natural to adopt the equation given above with these conditions which are part of the old Vedic astronomical tradition. Use of it in either region does not imply borrowing because it is the most obvious function to use.

### The Use of the Water Clock

The use of the water-clock occurs in the Atharvaveda 19.53.3 in the expression:[25]

*pūrṇaḥ kumbho'dhi kāla āhitaḥ*: A full vessel is placed upon kāla (time).

The objective of this mantra is to exhort that "a full vessel be set [up] with reference to the [measurement of] time."

Since the Atharvaveda is prior to the period of Babylonian astronomy by any account, it shows that India used water-clocks. Babylonia may have had its own independent tradition of the use of water-clocks.

### The Concept of the tithi

The division of year into equal parts of 30 portions is to be found in several places in the Vedas and the subsequent ancillary texts.

In RV 10.85.5, it is stated that the moon shapes the year. In the Taittirīya Brāhmaṇa the correct technical sense of the tithi is given at many places. For example, in TB 1.5.10, it is said that *candramā vai pañcadaśaḥ. eṣa hi pañcadaśyāmapakṣīyate. pañcadaśyāmāpūryate*, "the moon wanes in fifteen, and waxes in fifteen [days]." In TB 3.10, the fifteen tithis of the waxing moon and fifteen tithis of the waning moon are named.

The idea of the tithi is abstract. There are only 27 moonrises in a month of 29.5 days. To divide it into 30 parts means that a tithi is smaller than a day. The reason it arose in India was due to its connection to Soma ritual.

Since all the six concepts were already in use in the Saṃhitās, in an epoch earlier than 1000 BCE in the least, they could not have been learnt by the Indians from the Babylonians who came to use these concepts after 700 BCE

## The Great Year

Since the yuga in the Vedic and the Brāhmaṇa periods is so clearly obtained from an attempt to harmonize the solar and the lunar years, it appears that the consideration of the periods of the planets was the basis of the creation of an even longer yuga.

There is no reason to assume that the periods of the five planets were unknown during the Brāhmaṇa age. It was argued earlier in the book that the astronomical numbers in the organization of the Ṛgveda indicate with high probability the knowledge of these periods in the Ṛgvedic era itself.

Given these periods, and the various yugas related to the reconciliation of the lunar and the solar years, we can see how the least common multiple of these periods will define a still larger yuga.

In the Mahābhārata and the Purāṇas, the kalpa, the day of Brahmā, is 4,320 million years long. The night is of equal length, and 360 such days and nights constitute a "year" of Brahmā, and his life is 100 such years long. The largest cycle is 311,040,000 million years long at the end of which the world is absorbed within Brahman, until another cycle of creation. A return to the initial conditions (implying a superconjunction) is inherent in such a conception. Since the Indians and the Persians were in continuing cultural contact, it is plausible that this was how this old tradition became a part of the heritage of the Persians. It is not surprising then to come across the idea of the World-Year of 360,000 years in the work of Abū Ma'shar, who also mentioned a planetary conjunction in February 3102 BCE

The theory of the transmission of the Great Year of 432,000 years, devised by Berossos, a priest in a Babylonian temple, to

India in about 300 BCE, was advanced.[26] But we see this number used in relation to the Great Year in the Śatapatha Brāhmaṇa, a long time before Berossos.

The idea of superconjunction is at the basis of the cyclic calendar systems in India. The Śatapatha Brāhmaṇa, speaking of the marriage between the Seven Sages, the stars of the Ursa Major, and the Kṛttikās, is talking of the Saptarṣi centennial calendar with a cycle of 2,700 years. This calendar is still in use in several parts of India.

The existence of a real cyclic calendar shows that the idea of superconjunction was used in India much before the time of Berossos. This idea was used elsewhere as well but, given the paucity of sources, it is not possible to trace a definite place of origin for it.

The debate on the relationship between the astronomical sciences of India and Babylon became vitiated by the race and colonial theories of 19th century Indologists. Their analysis was done using simplistic ideas about cultural interaction in which knowledge was taken to flow from one direction to another. Considering that a time range of several centuries was involved and interaction through intermediaries constituted a complex process, the answer to any question of borrowing and influence can only be complicated.

The above evidence shows that in the period of the early Vedic texts, which is definitely prior to 1000 BCE, the following facts were known:

- Vedic astronomy tracked the motion of the sun and the moon against the backdrop of the nakṣatras. The sky was divided into 12 segments (Ādityas) and 27 segments (lunar nakṣatras) where the nakṣatra and deity names were used interchangeably.

- Although the names of the solar zodiacal signs (rāśis) are seen first in the siddhāntic texts, we derived them from the deity names of the lunar nakṣatra segments. Given that the nakṣatra names are to be found in the Saṃhitās and the rāśi names are not in the Vedic books, one concludes that the specific names were chosen sometime in the first millennium BCE, replacing the earlier Āditya names. But the solar signs were a very early component of Vedic astronomy, acknowledged in the Ṛgvedic hymn itself which speaks of the twelve division of the 360-part wheel of time.

- The use of the tithi system, the division of the lunar month

> into 30 parts, is closely connected to Soma worship, a uniquely Indian ritual. There is no such ritual connection with the tithis that we know of in the Babylonian context.

The evidence suggests that the Indian ideas of sacrifice, 12 divisions of the solar year, and the 30 divisions of the lunar month, and the zodiac reached Babylonia sometime before first millennium BCE. These new ideas, including the Indian ratio of 3:2 for the longest to shortest day of the year, triggered a new phase of careful observations in Babylonia which was to influence astronomy in a fundamental way.

But it is also possible that the Babylonian flowering was quite independent based on the presence of general ideas which were present in the lands across India to Greece. In any event, the borrowing was of the most general ideas, the actual methods were a continuation of the local tradition. Considering the details, we find that the astronomical systems of India and Babylon (and also Greece) each have unique features.

Subsequent to the establishment of the Indo-Greek states on the borders of India after Alexander, the interaction between Indian and Western astrology and astronomy entered a new phase. Increased political and trade interaction made it possible for texts to be exchanged.

# 13. *The Spread of Vedic Ideas*

## Astronomy as Crowning Science

Although the focus of the book is the astronomical code of the Ṛgveda, the evidence presented here allows us to sketch an account of the rise of astronomy in ancient India that, in turn, provides us insights into many different aspects of early Indian culture and civilization. The Purāṇas credit the legendary figure of Purūravas with the division of the one fire, of which he had learnt from the gandharvas, into three that are the basis of the Vedic fire ritual. One may conclude that the fire ritual, together with its astronomical basis, was a part of the Vedic religion for as long as the bards of the Purāṇas could remember. Corroboration of this view is obtained from the fact that the Greeks and the Romans also had fire ritual.

One may assume that either some fire ritual existed before the dispersal of the Indo-Europeans or having arisen somewhere it spread into the web of different Indo-European language speaking peoples through the process of migration and diffusion. Since current archaeological evidence suggests that such a dispersal occurred as early as 8000 BCE, astronomical concerns that were to be eventually reflected in the design of the three altars by Purūravas are very old. Conversely, if fire ritual spread from one Indo-European region to others, it is still likely to be very old because fire altars have been found in the Sindhu-Sarasvatī sites. Such an old tradition implies observations over millennia, which helped find several fundamental facts about the lunar and the solar years as well as the motions of the planets.

The Brāhmaṇas speak of ritual that parallels the passage of the year. Monthly rites like the darśapūrṇamāsa and seasonal rites like cāturmāsya required careful observation of the movements of the sun and the moon across months. Such rites necessitated the definition of the tithi, the division of the lunar year into 360 parts.

A specific session called gavāmayana was for the daily observation for the movements of the sun and the disappearance of the moon. No wonder astronomy as jyotiṣa was the crest jewel of the Vedic sciences.

In historical times too one sees importance accorded to time measurements. The Arthaśāstra of Kauṭilya describes (in the twentieth chapter of the second book) the duties of the mānādhyakṣa, or superintendent of measurements, among which is the duty of timekeeping. Time was measured by the gnomon and the waterclock.

The key that opened the knowledge of the astronomy of the Ṛgveda and the Śatapatha Brāhmaṇa was the idea of numerical equivalences. The areas of the fire altars correspond to the broad astronomical facts about the year. This key is inherent in the Upaniṣadic equivalence between the outer and the inner.

The fact that the altar increases by one unit area in each new construction indicates the intercalation that is necessary to bring the lunar year in line with the solar year. This increase goes on until the ninety fifth year when an additional correction is made to remove this error. We have sketched broad aspects of Ṛgvedic astronomy but its details remain to be deciphered.

The main elements of the astronomy of the Vedāṅga Jyotiṣa are already contained in the Śatapatha Brāhmaṇa. Specifically, we find clear references to the nominal year of 372 tithis, the nakṣatra year of 324 tithis, and a solar year of 371 tithis. The choice of 371 tithis for the solar year corresponds to 365.1949 days. But the fact that a further correction was required in 95 years indicates that these figures were known to be approximate.

Assuming intercalation at the end of the 95 year Yājñavalkya period, we conclude the duration of the year was 365.24675 days which is quite close to the tropical year. In view of this, the dating of second millennium for the Vedāṅga Jyotiṣa is not inconsistent with a conservative dating of 2nd millennium BCE for the Śatapatha Brāhmaṇa. Of course the Śatapatha Brāhmaṇa does not speak of any details of motions of planets, but that is not surprising considering that its main purpose is ritual associated with the sun and the moon.

There was a clear conception of the great yuga during the age of the Brāhmaṇas. The existence at the same time of the notion of the primal person being made out of $7\frac{1}{2}$ puruṣas, when a puruṣa is equated with 360 years leading to a longer cycle of 2700 years, suggests that the Saptarṣi era was known. That the nominal size of the Ṛgveda was considered to be 432,000 syllables suggests a theory of a much larger yuga of that extent in years since the Ṛgveda represented the universe symbolically.

One may theorize that the planetary periods were determined at the end of the Ṛgvedic age and incorporated in the code. It is possible that after the determination of these periods this knowledge became widespread and its significance in the organization of the Ṛgveda was forgotten.

Van der Waerden[1] argued that a primitive epicycle theory was known to the Greeks by the time of Plato. He argued such a theory might have been known in the wider Indo-European world by early first millennium BCE which led to the development of very different epicycle models in Greece and India.

The existence of an independent tradition of observation of planets and a theory thereof as suggested by our analysis of the Ṛgvedic code helps explain the puzzle why classical Indian astronomy of the Siddhānta period uses many constants that are different from that of the Greeks. This confirms the thesis that although Siddhāntic astronomy from the time of Āryabhaṭa developed in some knowledge of Greek methods, the reason why it retained its characteristic form was because it was based on an independent, old tradition.

Analysis of the Siddhāntic and the practical karaṇa texts by Billard[2] supports this conclusion. These texts provide a set of elements from which the planetary positions for future times can be computed. The first step in these computations is the determination of the mean longitudes which are assumed to be linear functions of time. Three more functions, the vernal equinox, the lunar mode and the lunar apogee are also defined. Billard investigated these linear functions for the five planets, two for the sun (including the vernal equinox) and three for the moon. He checked these calculations against the values derived from modern theory and he found that the texts provide very accurate values for the epochs when they were written. Since the Siddhānta and the karaṇa models are not accurate, deviations build up beyond the observation epoch. In other words, Billard refuted the theory that there was no tradition of observational astronomy in India.

The Vedic gods Mitra, Varuṇa, Indra and the Nāsatyas in the Hittite-Mitanni treaty of the second millennium BCE are Indian rather than Iranian, because Iranians would not have invoked Indra along with Varuṇa. The Indic element was intrusive into Southwestern Asia starting about the beginning of the second millennium, but even before that trade routes carried ideas in both directions. If the intrusion in the early second millennium BCE was triggered by the collapse of the Harappan economy caused by the desiccation of the Sarasvatī river around 1900 BCE, then one can see how this may have been accompanied by a transmission of the astronomy of the fire altars and the planetary period values of the Ṛgveda.

Continuing interaction in subsequent centuries is mirrored in parallels between Indian and Babylonian astronomies. We saw that the ratio of longest to shortest daylight changed from 1.29 to 1.5 as the focus of Vedic astronomy shifts from Sarasvatī valleys to Northwest India. The latter value is to be found in Vedāṅga Jyotiṣa of the latter half of the second millennium. One finds the same ratio of 1.5 in the Babylonian texts of the first millennium, although the earliest Babylonian texts spoke of a ratio of 2.0.

The other significant parallel that exists is that the Babylonian texts use a linear zig-zag function to determine the length of daylight in intermediate months which we have found is already present in the Ṛgvedic model. One might speculate that Vedic astronomy influenced the Babylonians who built upon it further during their own astronomical flowering in the middle of the first millennium BCE. If a primitive epicycle theory was also communicated then the parallels between the Greek and the Indian epicycle theories are a consequence of transmission of ideas.

The recognition of the central role of astronomy in the Vedic world view has significance for the interpretation of the Vedic literature. In particular, many hymns, hitherto considered paradoxical or unclear, become intelligible within the astronomical framework. Such an interpretation is consistent with the assertions within the Vedic tradition.

## Mathematics

The Vedas have many mathematical allusions and they speak of large numbers at many places. In the Vedic book called *Śatapatha Brāhmaṇa* (ŚB) (12.3.2), there is a sequence speaking of different successive divisions of the year that amounts to $10,800 \times 15^6$ parts. Elsewhere the number of stars is given as $1.08 \times 10^7$. Other numbers are used symbolically.

The texts have stories that have a mathematical basis. For example, the Maitrāyaṇī Saṃhitā 1.5.8 has the story of Manu with ten wives, who have one, two, three, four, five, six, seven, eight, nine, and ten sons, respectively. The one son allied with the nine sons, and the two sons allied with the eight, and so on until the five sons were left by themselves. They asked the father for help, and he gave them each a samidh, or "oblation-stick," which they used to defeat all of the other sons.

Since the ten sons did not ally with anyone, and the pairing of the others, excepting the five left over, is in groups of ten, the counting is in the base 10 system. In this mathematical story, the sticks help make the five stronger than the other 50. This happens because each stick has a power of 10, and therefore the 5 now have a total power of 55 which vanquishes the 50. This could imply knowledge of the place value system if one conjectures that each oblation-stick is in the higher place value so that 50+5=55.

There is some evidence that the Vedic sages knew the idea of primality. Vedic numbers, when they are primes or have large prime factors, may represent a count (say of words) or a representation of an abstraction, but the primality could conceivably just be an accident. But given that the Vedic seers put a lot of store in numbers, they could have adjusted the count to reflect a more desirable property of it. Some of the numbers may not even be actual counts, but rather ideal counts and, therefore, the choice of the number as a prime become even more significant. The Śatapatha Brāhmaṇa provides examples of systematic calculation of the divisors, suggesting that the Vedic people were aware that other numbers do not have divisors excepting 1 and the number itself. The number of divisors of numbers such as 720 and 10,800 were systematically calculated. It is significant that several key numbers in the Vedic texts are prime.

## Indic People in the West

The intrusion of Indic people—and presumably their ideas—in the Near East was mentioned before. The idea that these were Indo-European people migrating towards India does not agree with detailed facts. Their linguistic usage is different from that of the Iranians which rules out the undifferentiated Indo-Iranian phase and the already populated regions of West Asia could not have supported a huge migration of a foreign element through it without a memory of it in native chronicles. The Indo-European element continues to be present as a minority in precisely the same areas as was true for the second millennium BCE.

We noted that the Mitanni who, by the 15th century BCE had expanded their power from the shores of the Mediterranean to the Zagros mountains, invoked Vedic gods. Other Mitanni documents, uncovered in the archives at Bogazköy (Hittite) and El Amarna (Egypt) also point to Indic influences.

A Hittite text on horse-training and chariotry uses Sanskrit numerals; a Hurrian text uses Sanskrit words to describe the color of horses. The Kassites, who ruled Mesopotamia for several centuries in the second millennium BCE, had an Indic element, representing, here as elsewhere in the region, a ruling aristocracy. Many Egyptian pharaohs, including Akhenaten, had Mitanni queens, which may account for the parallels in the two religious traditions.[3]

This Indic element likely played a role in the development of the cultural and religious complexes of Egypt and the Near East in the second millennium BCE. The beginnings of this particular intrusion is seen around 1800 BCE. Around 1650, an Indic people occupied the Nile delta for about 100 years; these people are described as the Hyksos, "the Foreign Princes." Egypt's new eschatological visions and innovations in myth are the evidence for this presence, which flows in logical sequence out of their presence in West Asia. A still earlier intrusion of "Eastern" ideas into Egypt is assumed based on the readings of "Pyramid Texts" of about 2600 BCE. The military activity of the Hittite king Hattusilis is taken as the vehicle for this process.

A memory of the supremacy of the Indic (or Indo-Iranian) region in religious and legal ideas is preserved in an ancient Pahlavi text. The world is divided into three regions:[4] "the west (Rome) with riches; the north and east (Turkestan and the deserts) with martial turbulence; the south (Iran and India) with religion, law, and the supreme royalty besides."

## Venus and Vena

In Western lore, Venus is the planet and the Roman goddess of natural productivity and of love and beauty. The Greeks called this planet Aphrodite and also *Eosphoros* or the "bringer of light" when it appeared as a morning star, and *Hesperos* when it appeared as the evening star. It is believed that the Greeks first did not know that the two stars were the same but by the time of the Pythagoreans this identity was known. The Roman Venus derived her characteristics from the Greek Aphrodite who in turn was based on the Babylonian Ishtar. In Greek legend, Aphrodite was born in *Kupris* or Cyprus; Kupris, a feminine deity, was derived from the masculine *Kupros*. In India, there is the Ṛgvedic attestation (10.123) of Vena as the name for this planet.[5] Later texts use Śukra as another name. So we have have linguistic affinity in these names: Venus and Vena, Kupros and Śukra.

The Ṛgveda describes two aspects of Venus: one, as Gandharva, who is the patron of singing and the arts; and the other, who is the son of the sun and an asura. These conceptions, together with the meaning of Vena as "longing" and "love," lead to the later mythologies of India and West Asia.

It was suggested by Alvarez that the representation of the goddess in Mesopotamia and later on in Greece was under the influence of Indian ideas.[6] Perhaps the evidence of the first conceptualizations of the goddess can help us with the chronology of the ideas in India. Aphrodite, like Lakṣmī, is born out of the sea. But the Indian story is technically more consistent because here the birth is out of churning, like that of butter out of milk, whereas the circumstances of Aphrodite's birth are more fanciful. According to Hesiod in *Theogony 185-200*, she is nurtured in the foam produced when Kronos hacks off and tosses the genitals of his father, Ouranos, into the sea.[7] Also, Ishtar couldn't have been prior to Vena because Theogony has only one of the many elements to be found in the Ṛgvedic hymn 10.123.

Vena knows the secret of immortality. This presumably has reference to the fact that Venus emerges again after being obscured by the sun. In the Purāṇic glosses of this story, Śukra is swallowed up by Śiva and later on expelled as semen; this is a play on the etymology of Śukra as "bright." The birth of Aphrodite out of the genitalia of Ouranos is a similar story, in which instead of semen the nurturing is in foam. The Purāṇas tell us how the gods learnt the secret of immortality from Śukra by subterfuge. There is another remembrance of the immortality of Venus in the myth of Phoenix, a word cognate with Vena. Phoenix rises again after death, warmed by the rays of the sun.

The Indian sources, namely the Ṛgveda and the Purāṇas, explain the whole basis of the Vena-Śukra myth at several levels. In Mesopotamia and in Greece and Rome, only scattered meanings are encountered which lead us to the conclusion that these ideas traveled from India to Europe by way of Mesopotamia.

There exist other parallels. Dumézil[8] has compared episodes from the epics and the Purāṇas with European myths and found crucial similarity in detail. Although Dumézil invokes the tripartite underpinnings of the Indo-European thought to explain this similarity, it is more likely that there was some transmission of stories like the ones that occurred in the later transmission of Indian fables and Jātakas. The Indian stories are according to a self-conscious logic so the encyclopaedic authors of the Purāṇas had no trouble churning them out in large numbers. There is a deep and comprehensive exposition of the myths in the Indian texts. The European stories, in contrast, are disconnected. Nicholas Kazanas[9] shows that the Ṛgveda "contains a decisively greater portion of the common Indo-European mythological heritage. In fact there is hardly a major motif common in two or more of the other branches that is not found in the Ṛgveda." This is more true if the Purāṇic literature is considered.

## Art

Indian art has several unique features and motifs that are related to its cosmology.[10] These themes and motifs are seen in the rock art and Harappan seals and they also occur in the Near East and in Greece. One of these is the image of the "hero"—the "Gilgamesh" figure— of the rock art and Harappan seals.[11] This appears to validate the idea of interaction between India and its western regions in early centuries of the third millennium BCE.

We now look at a few specific forms and symbols from Western art for their Indian parallels.

### Heroes, sacrifice

Although the Kīrttimukha, a guardian of the threshold, is dated somewhat late in Indian art, its basis is squarely within the Indian mythological tradition. Zimmer[12]argued that the image of the Gorgon must be viewed as an intrusive Indic idea or a Greek interpretation of the Kīrttimukha assimilated atop a different legend. Napier[13] provides new support for this idea. He suggests that the forehead markings of the Gorgon and the single-eye of the cyclops are Indian elements. He suggests that this may have been a byproduct of the interaction with the Indian foot soldiers who fought for the Persian armies. But there were also Indian traders in Greece. Napier sees this in the name of the Mycenaean Greek city Tiryns — the place where the most ancient monuments of Greece are to be found— that sounds similar to that of the powerful Indian sea-faring people called the Tirayans.[14]

Napier shows that the Perseus-Gorgon story is replete with Indian elements, especially the connection of the myth with Lycia. "This ancient kindgom figures predominantly in Greek mythology as the location of the exotic: a place of ivory, peacocks, and 'many-eyed' cows; a place to which Greeks went to marry and assimilate that which to the pre-classical mind represented everything exotic... [In the British Museum] we find a Lycian building, the roof of which is clearly the descendant of an ancient South Asian style. Proof of this hypothesis comes not only in what may appear to be a superficial similarity, nor in the many 'Asian' references with which Lycia is associated, but in the very name of the structure which dates to the mid-fourth century BCE. For this is the so-called 'Tomb of the Payava' a Graeco-Indian Pallava if there was one. And who were the Tirayans, but the ancestors of two of the most famous of ancient Indian clans, the Pallavas and Cholas?"[15]

Napier's ideas are speculative in his use of the names Tirayan and Pallava that are attested much later in India. But his argument related to the occurrence of Indian motifs in Greece is sound.

**Funerary art**

Indian mythology has rich descriptions of Indra's city, the paradise, with its water nymphs and gardens. Octavio Alvarez[16] suggests that the Vedic themes of afterlife are sketched on Etruscan tombs. He traces their transmission via Egypt, where the souls were no longer received by the tragic death-god Osiris, but by the enchanting Hathor, the goddess of joy and love. Likewise, in the earlier Graeco-Roman conception of the afterworld, the souls were supposed to exist "without midriff," i.e., deprived of food and sex. But ultimately the ideas of the Vedic heaven, where in the city of Indra are all pleasures and eternal youth, displaced these older views, and Alvarez is able to explain the new symbols of resurrection used in the Etruscan and later funerary art. He establishes a connection between the water-nymphs in the Greco-Roman mythology and the apsarases of the Vedic mythology.

The western interpretation of Vedic afterlife was a literal rendering of a metaphor. The Vedic paradise transcends space and time and it represents an absorption into Brahman. The notion of paradise as a pleasure garden was later adopted by Islam.

Alvarez is able to explain the iconography of the Etruscan sea-sarcophagi very convincingly using Indian parallels. He describes eight basic elements:

1. The scene is the celestial ocean, abode of the departed souls, quite like Indra's paradise.

2. The females are the apsarases, water-nymphs. On early sarcophagi and sepulchral imagery they wear the Indian hairdo and earrings, but are otherwise nude, conforming to the Indian models. They are shown with prominent bellies and heavy backsides intentionally framed by drapes in the Indian manner.

3. The babies are the souls of the departed who reappear in paradise. This reappearance is connected to the idea of rebirth.

4. The flowers are the immediate vehicles of rebirth according to the idea of the birth out of Lotus.

5. The breast-feeding of the soul-babies shows the reception and nourishment by the heavenly hosts.

6. The sea-centauri are gandharvas. As the male counterparts and lovers of the apsarases, they show fins and fish-tails to set them apart from the Greco-Roman centauri.

7. The amorini who fill the atmosphere are the Mediterranean symbols to denote the celestial ocean, which is so glowingly described in India's eschatology.

8. The portrait of the deceased is shown within a sea-shell, no doubt to indicate the rebirth in the "Celestial Ocean."

There are other Indian elements in the iconography, such as garlands and the betel nut.

### The Gundestrup cauldron

The silver Gundestrup cauldron, found in Denmark a hundred years ago, is dated to around the middle of the 2nd century BCE. The sides are decorated with scenes of war and sacrifice: deities wrestling beasts, a goddess flanked by elephants, a meditating figure wearing stag's antlers. That the iconography must be Indic is suggested by the elephant (totally out of context in Europe) with the goddess and the yogic figure.

According to the art historian Timothy Taylor,[17] "A shared pictorial and technical tradition stretched from India to Thrace, where the cauldron was made, and thence to Denmark. Yogic rituals, for example, can be inferred from the poses of an antler-bearing man on the cauldron and of an ox-headed figure on a seal impress from the Indian city of Mohenjo-Daro...Three other Indian links: ritual baths of goddesses with elephants (the Indian goddess is Lakshmi); wheel gods (the Indian is Vishnu); the goddesses with braided hair and paired birds (the Indian is Hariti)." Taylor speculates that members of an Indian itinerant artisan class, not unlike the later Gypsies in Europe who originate in India, must have been the creators of the cauldron.

### Egyptian terracottas

Harle[18] examined terracottas excavated by Petrie at Memphis in Egypt and believed by him to be Indian. These figures date from the Greco-Roman period and it is accepted that an Indian colony existed in Memphis from about the 5th century BCE onwards. Reviewing the evidence, Harle concludes that the figures were made by Indian colonists.

Harle points to the pose, which in two cases is *lalitāsana* and *rājalīlāsana*. He adds:[19] "The plastic feeling, however hard to define, is also Indian. There are other features as well which recall certain Indian figures: the corpulence, a *dhoti*-like lower garment and, in one case, an armlet on the right arm and a scarf over the left shoulder. All these features point to an India Pancika (Kubera) from Gandhara of the early Pāñcika and Hārītī sculpture in the Peshawar Museum."

The figures include the one that has traditionally been taken to be Harpocrates, the son of Isis and Osiris. But it is possible that for the Indian colonists the figure represented Kṛṣṇa-Vāsudeva as the child-god. Two bronzes of this child-god have been found in Begram and Taxila.

## Migration and Diffusion

The findings of this book may be seen in the context that there is no discontinuity in India's archaeological record; the only breaks are due to ecological factors.[20]

In a review of the archaeological evidence Shaffer and Lichtenstein conclude:[21] "The South Asian archaeological record does not support ... any version of the migration/invasion hypothesis. Rather, the physical distribution of sites and artifacts, stratigraphic data, radiometric dates, and geological data can account for the

Vedic oral tradition describing an internal cultural discontinuity of indigenous population movements." They add, "As data accumulate to support cultural continuity in South Asian prehistoric and historic periods, a considerable restructuring of existing interpretive paradigms must take place. We reject most strongly the simplistic historical interpretations, which date back to the eighteenth century, that continue to be imposed on South Asian culture history. These still prevailing interpretations are significantly diminished by European ethnocentrism, colonialism, racism."

Indian literature remembers astronomical events that go back to the fourth or fifth millennium BCE. The presence of the Indic element in the Near East in the second millennium BCE is an intrusion from India or an intrusion by a group that was culturally Indianized. The drying up of Sarasvatī around 1900 BCE, which led to a major relocation of the population centered around in the Sindhu and the Sarasvatī valleys, was likely the event that caused a migration westward from India. It is soon after this time that the Indic element begins to appear all over West Asia, Egypt, and Greece.

The study of art provided evidence of the Indic element in the Greco-Roman world as in the case of the Gorgon, the sea-sarcophagi in Rome, the yogic figure and other deities on the Gundestrup cauldron, and the terracotta figures in Memphis. Ancient Eurasia had considerable trade and interaction within its regions, and this interaction was a complex process that included elements of diffusion and migration.

The book presented evidence of an early astronomy in the organization of the Ṛgveda, which is in accord with the astronomy of the fire altar ritual. This astronomy predates the astronomy of the West and is likely to have traveled West from India. Doubtless, other ideas traveled in the opposite direction.

# *Abbreviations for Sanskrit Texts*

| | |
|---|---|
| AA | Aitareya Āraṇyaka |
| AAr | Āryabhaṭīya of Āryabhaṭa |
| AB | Aitareya Brāhmaṇa |
| AB | Agni Purāṇa |
| AV | Atharvaveda |
| ASS | Āpastamba Śulbasūtra |
| BG | Bhagavadgītā |
| BP | Bhāgavata Purāṇa |
| BtS | Bṛhat Saṃhitā |
| BSS | Baudhāyana Śulbasūtra |
| BU | Bṛhadāraṇyaka Upaniṣad |
| CS | Chandaḥśāstra |
| CU | Chandogya Upaniṣad |
| JG | Jaiminīya Gṛhyasūtra |
| KB | Kauṣītaki Brāhmaṇa |
| MP | Matsya Purāṇa |
| PB | Pañcaviṃśa Brāhmaṇa |
| RV | Ṛgveda |
| RVJ | Ṛgveda Vedāṅga Jyotiṣa |
| ŚB | Śatapatha Brāhmaṇa |
| SS | Sūrya Siddhānta |
| SV | Sāmaveda |
| TB | Taittirīya Brāhmaṇa |
| TS | Taittirīya Saṃhitā |

| | |
|---|---|
| VaP | Vāyu Purāṇa |
| ViP | Viṣṇu Purāṇa |
| VJ | Vedāṅga Jyotiṣa |
| YV | Yajurveda |
| YVJ | Yajurveda Vedāṅga Jyotiṣa |

# *Notes*

## Preface

1. J. Gonda (1986), p. 87. The attempt to see layers of Indian literature as representing different evolutionary stages of culture has led to much misunderstanding.

2. e.g. Penrose (1989), p. 420. The case can be made that all discovery is spontaneous and it springs from the infinite potential of the spirit within us.

## Chapter 1: Introduction

1. The question of the relative chronology of ideas in the Vedic books is a vexed one. It is normally assumed that the books can be placed in a clear chronological sequence, but it is quite probable that the Vedic times had several traditions which were collected in different books. In other words, both the six-day as well as the seven-day weeks could be equally ancient. Likewise, there were equally old traditions related to the counts of the days by the motions of the sun and the moon.

2. Sastry (1985) also provides a historiography of this book.

3. Burgess (1860), pp. 388-392.

4. Gonda (1975).

5. Raster (1992), p. 9.

6. Dandekar (1958).

7. Heesterman (1957), p. 6. The psychological expansion of the inner space of the yajamāna is made possible by the homology between the inner and the outer.

8. Pargiter (1922) provides the Purāṇic and epic framework of kings and ṛṣis through about one hundred generations until the Vedic texts received their canonical form. This is discussed at length in Chapter 3.

9. Frawley (1991), Roy (1975), Sengupta (1938, 1947), Shamasastry (1938), Tilak (1893).

10. Kak (1992a).

11. Francfort (1992).

12. Seidenberg (1962, 1978).

13. Vidyālaṅkāra (1985).

14. The following statement,*yāṃ paryastamayam utsarped iti sa tithi*, in the Aitareya Brāhmaṇa 7.11 (32.10) is the earliest definition of tithi that we encounter. But as it reads it is ambiguous and therefore we must obtain the nature of the usage of this term from the context.

## Chapter 2: The Context of Vedic Studies

1. Staal (1989); see Frawley (1992) for yogic explanations.

2. Anthony, Telegin, and Brown (1991).

3. See, for example, Shaffer (1984) or Shaffer (1992); these papers provide extensive bibliographies.

4. Seidenberg (1978).

5. Mallory (1989).

6. See, for example, Oppenheimer (2004).

7. Planck (1950).

8. Childe (1926).

9. Gimbutas (1973, 1985).

10. Ammermann and Cavalli-Sforza (1984).

11. Renfrew (1987).

12. Mallory (1992).

13. Majumdar (1951). The theory of an Indian homeland of the Indo-Europeans is based on the antiquity of the Indian literature, absence of references to regions outside of northwest India in the earliest layers of this literature, and the commonly accepted theory that the Indo-Europeans moved into Europe after 6000 B.C.E.
14. Meillet (1967).
15. Mallory (1989), p. 114.
16. Dumézil (1988).
17. Benveniste (1973).
18. Brecher and Feirtag (1979), Deppert (1983).
19. It is hard to conclusively establish which tradition came first, that of 27 nakṣatras or 28 nakṣatras. Thus the Kāṭhaka Saṃhitā 39.13 has 27 whereas the Maitrāyaṇī Saṃhitā 2.13.20 has 28. The Taittirīya Brāhmaṇa has both counts in different books and the longer count appears in a later book.
20. These dates are taken from Sastry (1985). Further dates are provided in Sengupta's *Indian Chronology* (1947) that define a generally consistent framework. For Indian archaeoastronomy, see Kak (2010).
21. Sengupta (1947).

## Chapter 3: Chronology of the Vedic Texts

1. Jarrige and Meadow (1980), Possehl (1982), Kenoyer (1989), Shaffer (1992). To call the tradition by the name *Indus* is a colonial hangover. The river after which this tradition is sometimes named is not called Indus by either the Indians or the Pakistanis. The river's modern name is Sindh and in Sanskrit literature it is called Sindhu.
2. Mitchiner (1973).
3. Ammerman and Cavalli-Sforza (1984).
4. Sokal, Oden, and Wilson (1991).
5. Shaffer and Lichtenstein (1989), Shaffer (1992).

6. Gupta (1993).
7. Meadow (1989) page 61.
8. Misra (1992).
9. Possehl and Raval (1989).
10. Francfort (1992).
11. Rao (1979), Lal (1984), Thapar (1985).
12. Dhavalikar and Atre (1989).
13. Sarianidi (1977). It is important to recognize that these maṇḍalas can only be seen as a late development in Indian art. To find them in existence in 2000 B.C.E. requires a long pre-history. Parpola (1985, p. 77) identifies the architectural complex with three concentric walls as the tisraḥ puraḥ of the Asuras and the dasyus. But even this identification is consistent with the ongoing struggle between the Āryans of the Indus-Sarasvatī world and their northern neighbors.
14. Kak (1993d).
15. Mahadevan (1977), Joshi and Parpola (1987).
16. Fabri (1935), Mainkar (1984).
17. Kak (1988, 1989, 1990).
18. Rao (1982).
19. Gimbutas (1973, 1985), Renfrew (1987) present ideas that support an early presence of the Vedic people in India.
20. An important view on the interval necessary for the development of the Vedic literature is that of Winternitz (1909; 1981). Writing when he thought that no external evidence may be available to help with the dating: "As all the external evidence fails, we are compelled to rely on the evidence arising out of the history of Indian literature itself for the age of the Veda. The surest evidence in this respect is still the fact that Pārśva, Mahāvīra and Buddha pre-suppose the entire Veda as a literature to all intents and purposes completed, and this is a limit which we must not exceed. We cannot, however, explain the development of the whole of this great

literature, if we assume as late a date as round about 1200 B.C.E. or 1500 B.C.E. as its starting point. We shall probably have to date the beginning of this development about 2000 or 2500 B.C.E." (page 288)

21. Talageri (1993).

22. Pargiter (1922), p. 89.

23. Pargiter (1922), in his Preface.

24. Pargiter (1922), pp. 16-18.

25. Pargiter (1913, 1922).

26. Pargiter (1922), p. 177.

27. Pargiter (1922), p. 306.

28. Bhargava (1971).

29. Pargiter (1913), page 75.

30. Mitchiner (1982), p. 157.

31. Roy (1977).

32. Kar (1916).

33. Cunningham (1883).

34. Mitchiner (1982).

35. Cunningham (1883).

36. Sengupta (1947).

37. Cunningham (1883).

## Chapter 4: The Astronomy of the Fire Altars

1. For general references to the fire altars see Sen and Bag (1983) and Tripathi (1990). The astronomy of the fire altars was first presented in Kak (1992b, 1993a,c).

2. Tilak (1893), Kramrisch (1981).

3. Kuiper (1983). For a discussion of the parallels between Indra and Śiva see Frawley (1991).

4. Santillana and Dechend (1969).

5. Seidenberg (1978, 1983).

6. Translation by A.B. Keith in his *Rigveda Brahmanas*, London 1920.

7. Translation by A.B. Keith (see above).

## Chapter 5: The Architecture of the Ṛgveda

1. Sarasvati and Vidyalankar (1987).

2. Raster (1992).

3. See Macdonell (1886) for a translation of Kātyāyana's Sarvānukramaṇī that provides us the Ṛgvedic numbers.

4. Note that Kāṭhaka, Kapiṣṭhala and Maitrāyanīya do not occur in the Purāṇic accounts which suggests that they may be later than the other recensions. This also indicates that the listing of 28 nakṣatras in the Maitrāyanīya Saṃhitā should not carry as much weight as the account in the Taittirīya Saṃhitā.

5. Yājñavalkya Vājasaneya, the originator of the Vājasaneyi Saṃhitā, "was prior to Janamejaya III as his teaching appears to have been adopted by that king, for, it is said, Janamejaya established the Vājasaneyaka school in disregard of a Vaiśampāyana and in spite of his curse, but ultimately abdicated... This Vaiśampāyana can hardly have been Vyāsa's disciple, chronologically. He may have been the Vaiśampāyana of the Mahābhārata; but there he has been confused with Vyāsa's disciple." (Pargiter 1922, page 324)

6. This figure is obtained from the Anukramaṇī tradition.

7. Sarasvati and Vidyalankar (1987).

## Chapter 6: The Ṛgvedic Code

1. That these numbers are not random is clear when they are contrasted with the uninteresting Aṣṭaka numbers. The code first appeared in Kak (1992b, 1993b,c,d).

2. Kak (2005a,b, 2006).

3. The use of the code to determine the latitude of the place of the composition of the hymns was presented in Kak and Frawley (1992).

4. Björn Merker, "Rig Veda riddles in nomad perspective", *Mongolian Studies*, vol. 11, 1988, pages 35-41 uses the parallels in the Mongolian myths to suggest that the seven-wheeled chariot of the Ṛgveda are the Seven Sages. The One that the poets then address is the pole star, which in Merker's computation would have been Thuban in the Drago constellation. Merker informs me (personal communication) that the above paper incorrectly indicates the second millennium B.C.E. for this epoch; it should correctly be prior to the middle of the third millennium B.C.E.

## Chapter 7: The Code in the Atharvaveda

1. See Ježić (1986).

2. Schrader (1930) who also discusses issues related to the canonicity of the standard text of the Bhagavadgītā.

3. Gonda (1975), page 272.

4. For issues related to the indexing of the hymns of the Atharvaveda see Whitney (1905); see especially the comments of C.R. Lanman in his introduction to the book where the Pañcapaṭalikā and the Bṛhatsarvānukramaṇī notices regarding the organization are examined. For details of the difference of 188 verses in the total given by Whitney and the Bombay edition of S.P. Pandit see Whitney (1905, page cxxxvii). Lanman counts the total to 5,226 verses on page cxlvii.

5. See Whitney (1905, page cxxx) where Lanman argues against Whitney's division of Books 15 and 16.

## Chapter 8: On the Distance to the Sun

1. Neugebauer (1975).

2. Caland (1982).

3. Sarup (1920-29).

4. Van der Waerden (1974).

5. Shukla and Misra (1976).

## Chapter 9: The Asymmetric Circuit of the Sun

1. Eggeling (1988; originally 1882-1900).
2. Caland (1926).
3. Thurston (1994).
4. Kramrisch (1981).
5. Kak (1997, 1998f).
6. Sastry (1985).
7. ŚB 8.2.1.1
8. ŚB 8.3.1.1
9. ŚB 8.4.1.1
10. ŚB 8.5.1.1
11. ŚB 8.6.1.1
12. ŚB 8.5.4.12
13. That Eggeling (1988; originally 1882-1900)was aware that there was a discrepancy in his interpretation and the descriptions in the text is shown by his Note 2 on page 128 where he says, "Bricks would seem, in the fifth layer, to lie by half a foot further away from the central point..."
14. Imbrie and Imbrie (1986).

## Chapter 10: The Vedāṅga Jyotiṣa

1. Sastry (1985), Kak (1995a).
2. Kramrisch (1976).
3. Kak (1995b).

## Chapter 11: The Cosmology of the Purāṇas

1. Müller (1890).
2. De, S.S. in Pandya et al (1992), Vartak (1995), Kak (1998d).
3. Shrava (1977).
4. Larson and Bhattacharya (1987).
5. Seal (1985).
6. Kak (2001b).
7. Kak (1998e).
8. Shukla (1976).
9. Kak (2009a) and Kak (2009b) based on interpretation of lengths of old monuments by Danino (2005), Balasubramaniam (2008) and Balasubramaniam and Joshi (2008).
10. Kak (2004).

## Chapter 12: Vedic and Babylonian Astronomy

1. Kak (2007).
2. Burrow (1973).
3. S.N. Sen, "Surveys of Studies in European Languages." *Indian Journal of History of Science,* vol 20, 49-121, 1985.
4. E. Leach, "Aryan invasions over four millennia." In *Culture through Time, Anthropological Approaches*, E. Ohnuki-Tierney (ed.), Stanford, 1990, pp. 227-245. See also, Kak (2001).
5. D. Pingree, "History of mathematical astronomy in India." In *Dictionary of Scientific Biography*, C.S. Gillespie, ed., 533-63 3. New York: Charles Scribner's Sons, 1981.
6. Pingree suggests indirectly (*op cit*) that the Ṛgvedic hymns with the 360 divisions of the year must be dated around 500 BC because this knowledge arose in Babylonia!
7. Burgess (1860).

8. Kak (1996).

9. D. Pingree, "The Mesopotamian origin of early Indian mathematical astronomy." *Journal of the History of Astronomy,* vol. 4, 1-12, 1973. D. Pingree, "The recovery of early Greek astronomy from India." *Journal for the History of Astronomy,* vol 7, 109-123, 1976.

10. D. Pingree, In *Dictionary of Scientific Biography*, *op cit.* This goes against linguistic, historical, and geographical evidence in the Vedic texts and would be rejected by any scholar of Indian literature. For details of the chronology of Indian texts, see Winternitz (1909).

11. S.B. Dīkṣita, *Bhāratīya Jyotiśśāstra.* Hindi Samiti, Lakhanau, 1963 (1896).

12. D. Pingree, "Astronomy and astrology in India and Iran," *Isis,* vol 54, 229-246, 1963.

13. D. Pingree, "The Mesopotamian origin of early Indian mathematical astronomy," 1973, *op cit*, page 10.

14. See, for example, N. Achar, "On the Vedic origin of the ancient mathematical astronomy of India." *Journal of Studies on Ancient India*, vol 1, 95-108, 1998.

15. Billard (1971).

16. Van der Waerden (1980).

17. S. Kak, "Birth and early development of Indian astronomy." In *Astronomy Across Cultures: The History of Non-Western Astronomy*, H. Selin (ed.), pp. 303-340. Dordrecht: Kluwer Academic Publishers, 2000.

18. Neugebauer (1975).

19. N. Achar, "On the identification of the Vedic nakṣatras," In *Contemporary Views on Indian Civilization*, Proceedings of the WAVES Conference, held in Hoboken NJ, 2000. (ed) BhuDev Sharma, pp 209-229.

20. N. Achar, "In search for nakṣatra in Ṛgveda," In *Contemporary Views on Indian Civilization*, Proceedings of the WAVES Conference, Hoboken NJ, 2000. BhuDev Sharma (ed.), pp 200-208.

21. Kak (2002).
22. Aaboe, *op cit.*
23. O. Neugebauer, *op cit.*
24. Pingree, 1973, *op cit*, page 9.
25. B.N. Achar, *op cit.*
26. B.L. van der Waerden, "The great year in Greek, Persian and Hindu astronomy." *Archive for History of Exact Sciences,* vol 18, 359-384, 1978.

## Chapter 13: The Spread of Vedic Ideas

1. Van der Waerden (1974) and also Kak (1987a).
2. By means of a computer analysis of data Billard (1971) was able to establish that the Siddhāntic astronomical tables were based on actual observations made in the epochs of their writing.
3. Kak (2007).
4. Dumèzil (1973).
5. Kak (1996).
6. Alvarez (1978).
7. Athanassakis (1983).
8. Dumèzil (1970, 1983).
9. Kazanas (1998). More detailed arguments are presented in Kazanas (2006, 2007)
10. Kak (1998a, 2005a, 2005b, 2006)
11. Kak (1996).
12. Zimmer (1946).
13. Napier (1986, 1992).
14. Krishna (1980).
15. Napier (1998).

16. Alvarez (1978).
17. Taylor (1992).
18. Harle (1992).
19. Harle (1992).
20. Kak (1998a, 2001a).
21. Shaffer and Lichtenstein (1998).

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