Astronomy and its Role in Vedic Culture

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That astronomy played a very central role in Vedic culture is apparent from the innumerable references to nakṣatras and devas (heavenly bodies) in the earliest texts and the continuing cycle of ceremonies related to the calendar. Vedic astronomy was not based on the use of accurate clocks, but fine time units were defined in relation to events across longer durations. To preserve correspondence between lunar and solar years, intercalary months were inserted at regular intervals[1].

Astronomy is one of the six Vedāṅgas, subsidiary sciences, of the Vedas, the others being phonetics, ritual, etymology, grammar and metrics. The beginnings of these sciences are to be traced to the earliest parts of the Vedic literature; but the Vedāṅgas have come down to us in late forms in the aphoristic *sūtra* style. The construction of altars and the performance of ritual, kalpa, had an astronomical basis and we also find valuable astronomical information in the Śulbasūtras, which are a part of the Kalpasūtras. Two old names for astronomy are jyotiṣa, 'the science of light,' and nakṣatra vidyā, 'the science of stars.'

This article describes the position of astronomy in the larger knowledge system of the Vedic Indians. It also sketches the elements of the formal astronomy represented in the Vedāṅga Jyotiṣa, the earliest extant manual describing the motions of the sun and the moon.

1 The Vedic System of Knowledge

When the Vedic Saṃhitās are taken together with the Brāhmaṇas, Āraṇyakas, Upaniṣads, and Sūtras as well as the Vedāṅgas and the Upavedas, this body of texts encompasses a variety of sciences, psychology, and cosmology. The uniqueness of this knowledge arises from the multifarious interrelationships between the parts and how these parts are related to the whole. To understand any single Vedic text it is essential to know the Vedic system of knowledge. This system has a recursive nature where patterns and metaphors are repeated at different levels of description.

At the broadest level the classification of knowledge is in terms of aparā (material) and parā (transcendental). Speech and language are considered to have four forms[2], of which one kind, the parā, is unmanifest. In other words it is believed that ordinary language cannot express all aspects of the nature of reality. 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 and riddle.

Several texts mention that the Vedas are eternal or apauruṣeya. We are told that Prajāpati, Time, created the Vedas. It is stated that three lights (*jyotis*), Agni, Vāyu, and Āditya, were first produced[3]. 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*. This creation process clearly alludes to an astronomical basis. The ṛṣis are stars but they have counterparts in the firmament of consciousness. The hymns attributed to the ṛṣis are to be taken to have been seen in the inner space. 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. From another perspective, the Vedic chants and symbols represent archetypes of human consciousness, and it is in this sense that the Vedic knowledge is to be considered eternal.

The notion of equivalence or connection (*bandhu*) amongst the adhidaiva (devas or stars), adhibhūta (beings), and adhyātma (spirit) plays a central role in the Vedic system of knowledge. These connections, between the astronomical, the terrestrial, the physiological and the psychological, represent the constant theme in the discourse of the texts. They are usually stated in terms of vertical relationships, representing a recursive system; but they are also described horizontally across hierarchies where they represent metaphoric or structural parallels. Most often, the relationship is defined in terms of numbers or other characteristics. An example is the 360 bones of the infant—which later fuse into the 206 bones of the adult—and the 360 days of the year. Likewise, the tripartite division of the cosmos into earth, space, and sky is reflected in the tripartite psychological aspects of tamas, rajas and sattva.[4]

Although the Vedic books speak often about astronomical phenomena, it is only recently that the astronomical substratum of the Vedas has been examined[5]. One can see a plausible basis behind many connections. 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. There are quite precise biological clocks of 24-hour (according to the day), 24 hour 50 minutes (according to the lunar day since the moon rises roughly 50 minutes later every day) or its half representing the tides, 29.5 days (the period from one new moon to the next), and the year. Monthly rhythms, averaging 29.5 days, are reflected in the reproductive cycles of many marine plants and those of animals. The menstrual period is a synodic month and the average duration of pregnancy is nine synodic months. There are other biological periodicities of longer durations. These connections need not be merely numerical. In its most general form is the Upaniṣadic equation between the self (ātman) and the universe (brahman).

It is tempting to view *jyotiṣa*, the science of light, as the fundamental paradigm for the Vedic system of knowledge. Jyotiṣa is a term that connotes not only the light of the outer world, but also the light of the inner landscape. Astronomy is best described as nakṣatra-vidyā of the Chāndogya Upaniṣad, but because of its popularity we will also use jyotiṣa in its narrow meaning of astronomy. As defining our place in the cosmos and as a means to understand the nature of time, astronomy is obviously a most basic science.

That astronomy reveals that the periods of the heavenly bodies are incommensurate might have led to the notion that true knowledge lies beyond empirical aparā knowledge. On the other hand, it is equally likely that it was a deep analysis of the nature of perception and the paradox of relationship of the perceptor to the whole that was the basis of Vedic thought, and the incommensurability of the motions in the sky was a confirmation of the insight that knowledge is recursive. This Vedic view of knowledge seems to have informed the earliest hymns so it does not appear to be feasible to answer the question of which came first. Neither can we now answer the question whether jyotiṣa as pure astronomy was a precursor to a jyotiṣa that included astrology.

Analysis of texts reveals that much of Vedic mythology is a symbolic telling of astronomical knowledge. Astronomy was the royal science not only because it was the basis for the order in nature, but also because the inner space of man, viewed as a microcosm mirroring the universe, could be fathomed through its insights.

1.1 Of Ceremonies, Festivals, Rites

The importance of jyotiṣa for agriculture and other secular purposes are obvious and so we begin with a brief account of rites and festivals. These ceremonies and rituals reveal that there existed several traditions of astronomical lore; these variations are marked by the different books of Śrautasūtra. Such variation is perfectly in accord with an age when astronomy was a living science with different scholars providing different explanations. Since our purpose is not to go into the details of the Vedic texts, we will describe ceremonies and rites selectively.

Different points in the turning year were marked by celebrations. The year, beginning with the full moon in the month Phālguna (or Caitra), was divided into three four-monthly, *cāturmāsya*, sacrifices. Another way of marking the year is by a year-long dīkṣā. The year was closed with rites to celebrate Indra Śunāśīra (Indra with the plough) to "obtain the thirteenth month;" this thirteenth month was interposed twice in five years to bring the lunar year in harmony with the solar year. This closing rite is to mark the first ploughing, in preparation for the next year. Symbolically, this closing was taken to represent the regeneration of the year.

Year-long ceremonies for the king's priest are described in the Atharvaveda Pariśiṣṭa; these include those for the health of horses, the safety of vehicles, and so on. There existed other royal rites such as rājasūya, vājapeya and the aśvamedha, the so-called horse sacrifice, which actually represented the transcendence by the king of time in its metaphorical representation as horse. The primary meaning of aśva as the sun is attested to in the Ṛgveda, Nirukta, and Śatapatha Brāhmaṇa.[6]

The Gṛhyasūtras describe rites that mark the passage of the day such as the daily agnihotra. Three soma pressings, at sunrise, midday and sunset, were a part of the daily ritual of agniṣṭoma. Then there were the full and new moon ceremonies. Longer soma rites were done as sattras, sessions of twelve days or more.

1.2 Altars

Altar ritual was an important part of Vedic life and we come across fire altars in the Ṛgvedic hymns. Study of Vedic ritual has shown that the altar, adhiyajña, was used to show the connections between the astronomical, the physiological and the spiritual symbolically. That the altars represented astronomical knowledge is what interests us in this article. But the astronomy of the altars was not systematically spelled out although there are pointed references in many texts including the tenth chapter of Śatapatha Brāhmaṇa entitled Agnirahasya. Ṛgveda itself is viewed as an altar of mantras in the Śulbasūtras.[7]

Altars were used in relation to two basic types of Vedic ritual: Śrauta and Gṛhya. This ritual marked specific points in the day or the year as in the soma rituals of agniṣṭoma and agnicayana.[8] 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. The text says clearly that agnicayana represents ritual as well as knowledge.[9]

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.

The nominal year of 360 days was 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 there are three fire altars 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 descendents. It is a perpetual fire from which the 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 called the vedi and it is meant for the gods to sit on.

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).

Agnicayana altars are supposed to symbolize the universe.[10]Gārhapatya represents the earth, the dhiṣṇya hearths represent space, and the āhavanīya altar represents sky. This last altar is made in five layers. The sky is taken to represent the universe therefore 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, whereas the fourth layer represents the joining of space and sky.

Time is represented by the metaphor of a bird. The months of the year were ordinarily divided into six seasons unless the metaphor 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.

The Vedic sacrifice is meant to capture the magic of change, of time in motion. Put differently, the altar ritual is meant to symbolize the paradoxes of separation and unity, belonging and renunciation, and permanence and death. The yajamāna, the patron at whose expense the ritual is performed, symbolically represents the universe.

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.

1.3 Evolution of Vedic Thought

How did the use of altars for a symbolic representation of knowledge begin? This development 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 framework in which the composition of the different hymns can be seen.[11]The ideas can then be checked against social processes at work as revealed by textual and archaeological data.

As we will see later in this article, there existed an astronomical basis to the organization of Ṛgvedic itself; this helps us see Vedic ritual in a new light. That astronomy could be used for fixing the chronology of certain events in the Vedic books was shown more than a hundred years ago by Tilak and Jacobi.[12]This internal evidence compels the conclusion that the prehistory of the Vedic people in India goes back to the fourth millennium and earlier. On the other hand, new archaeological discoveries show a continuity in the Indian tradition going as far back as 7000 B.C.E.[13]These are some of the elements in accord with the view that the Vedic texts and the archaeological finds relate to the same reality.

Recent archaeological discoveries establish that the Sarasvatī river dried up around 1900 B.C.E. which led to the collapse of the Harappan civilization that was principally located in the Sarasvatī region. Francfort has even argued that the Dṛṣadvatī was already dry before 2600 B.C.E.[14]The region of the Sarasvatī and the Dṛṣadvatī rivers, called Brahmāvarta, was especially sanctified and Sarasvatī was one of the mightiest rivers of the Ṛgvedic period. On the other hand, Pañcaviṃśa Brāhmaṇa describes the disappearance of Sarasvatī in the sands at a distance of forty days on horseback from its source.[15]With the understanding of the drying up of Sarasvatī it follows that the Ṛgvedic hymns are generally anterior to 1900 B.C.E but if one accepts Francfort's interpretation of the data on the Dṛṣadvatī then the Ṛgvedic period includes the period before 2600 B.C.E.

2 Nakṣatras

The Ṛgveda describes the universe to be infinite. Of the five planets it mentions Bṛhaspati (Jupiter) and Vena (Venus) by name[16]. 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 was called a nakṣatra. Specific stars or asterisms were also termed nakṣatras. Śatapatha Brāhmaṇa relates a story[17]about the nakṣatras being as powerful as the sun in earlier times but that they have lost this power to the sun. In view of this the etymology *na* + *kṣatra*, 'no power,' is proposed. A favored modern etymology is *nak-kṣatra*, 'ruler over night.' One ancient name of astronomer is nakṣatra-darśa.

Nakṣatras are mentioned in the Ṛgveda and Taittirīya Saṃhitā specifically mentions that they are linked to the moon's path. The Ṛgvedic reference to 34 lights apparently means the sun, the moon, the five planets, and the 27 nakṣatras. In later literature the list of nakṣatras was increased to 28. Constellations other than the nakṣatras were also known; these include the Ṛkṣas (the Bears), the two divine Dogs (Canis Major and Canis Minor), and the Boat (Argo Navis). Aitreya Brāhmaṇa speaks of Mṛga (Orion) and Mṛgavyādha (Sirius). The moon is called sūrya raśmi, one that shines by sunlight.

Śatapatha Brāhmaṇa provides an overview of the broad aspects of Vedic astronomy. 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. It has been argued that these refer to stars or constellations. Viśvanātha Vidyālaṅkāra[18]suggests that these should be identified as the sun (Aśva), Gemini (Rāsabha), Aja (Capricorn) and Kūrma (Cassiopeia). This identification is supported by etymological considerations. RV 1.164.2 and Nirukta 4.4.27 define Aśva as the sun. Rāsabha which literally means the twin asses are defined in Nighanṭu 1.15 as Aśvinau which later usage suggests are Castor and Pollux in Gemini. In Western astronomy the twin asses are to be found in the next constellation of Cancer as Asellus Borealis and Asellus Australis. Aja (goat) is defined by Nighanṭu 1.15 as a sun and owing to the continuity that we see in the Vedic and later European names for constellations (as in the case of the Great Bear) it is reasonable to identify it as the constellation Capricorn (*caper* goat + *cornu* horn). Kūrma is a synonym of Kaśyapa (tortoise) which is linguistically close to Cassiopeia (from Greek Kassiopeia). Etymologically Kāśyapīya, slow like a tortoise, seems appropriate for Cassiopeia (from Greek Kassiopeia) since it is near the pole. This last name may point to an epoch when this constellation was even closer to the north pole.

Vedic ritual was based on the times for the full and the new moons, solstices and the equinoxes. The year was known to be somewhat more than 365 days and a bit less than 366 days. The solar year was marked variously in the many different astronomical traditions that marked the Vedic world. In one tradition, an extra eleven days, marked by ekādaśarātra or eleven-day sacrifice, were added to the lunar year of 354 days. According to the Taittirīya Saṃhitā five more days are required over the nominal year of 360 days to complete the seasons, adding that four days are too short and six days are too long. In other traditions, Gavāmayana, 'the walk of cows or intercalary periods,' varied from 36 days of the lunar sidereal year of 12 months of 27 days, to 9 days for the lunar sidereal year of 13 months of 27 days to bring the year in line with the ideal year of 360 days; additional days were required to be in accord with the solar year.

The year was divided into two halves: uttarāyana, when the sun travels north, and dakṣiṇāyana, when the sun travels south. According to Kauṣītaki Brāhmaṇa, the year-long sacrifices began with the winter solstice, noting the occurrence of the summer solstice, viṣuvant, after six months.

The twelve tropical months, and the six seasons, are named in the Yajurveda:

> Madhu, Mādhava in vasanta (spring);
> Śukra, Śuci in grīṣma (summer);
> Nabha, Nabhasya in varṣā (rains);
> Iṣa, Ūrja in śarada (autumn);
> Saha, Sahasya in hemanta (winter);
> Tapa, Tapasya in śiśira (freeze).

The nākṣatra names of the months began with Caitra in spring, although some lists begin with Phālguna. Since the months shift with respect to the twelve nakṣatra about 2,000 years per nakṣatra, this change in the lists indicates a corresponding long period. The lists that begin with Caitra mark the months thus:

> Caitra, Vaiśākha,
> Jyaiṣṭha, Āṣāḍha,
> Śrāvaṇa, Bhādrapada,
> Āśvina, Kārttika,
> Mārgaśira, Pauṣya,
> Māgha, Phālguna.

The earliest lists of nakṣatras in the Vedic books begin with Kṛttikās, the Pleiades; much later lists dating from sixth century C.E. begin with Aśvinī when the vernal equinox occurred on the border of Revatī and Aśvinī. Assuming that the beginning of the list marked the same astronomical event, as is supported by other evidence, the earliest lists should belong to the third millennium B.C.E. Taittirīya Saṃhitā 4.4.10 and Śatapatha Brāhmaṇa 10.5.4.5 each mention 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]

The following is a list of the nakṣatras and their locations:

1. **Kṛttikā**, from the root *kṛt*, 'to cut.' These are the Pleiades. Śatapatha Brāhmaṇa says that the Kṛttikās do not swerve from the east; this indicates early third millennium B.C.E.

2. **Rohiṇī**, 'ruddy,' is α Tauri, Aldebaran. The legend of Prajāpati, Orion, considered the personification of the year, pursuing his daughter, Rohiṇī, refers to the age when the beginning of the year shifted from Orion to Rohiṇī. In this legend Prajāpati's head was cut off by Mṛgavyādha, Sirius. In another version of this legend Śiva cuts off the head of Dakṣa Prajāpati. Such a shifting of the year occurred in the fifth millennium B.C.E. Atharvaveda 13.1.22 recalls the period when the sun rose in Rohiṇī.

3. **Mṛgaśīrṣa**, 'Orion's head.' Since the head of Orion was cut off, this is the region of the stars λ, ϕ_1, ϕ_2 Orionis. Another name of this nakṣatra is Āgrahāyana, 'the beginning of the year,' which is a cognate of the word Orion. The vernal equinox lay in Orion around 4500 B.C.E.

4. **Ārdrā**, 'moist,' is the brilliant star Betelgeuse, α Orionis.

5. **Punarvasū**, 'the two that give wealth again,' are the stars Castor and Pollux, or α and β Geminorum.

6. **Tiṣya**, 'pleased,' or **Puṣya**, 'flowered,' refers to the age when these stars, $\alpha, \beta, \gamma, \delta$ Cancri, formed the background to the sun during the summer solstice.

7. **Āśreṣā** or **Āśleṣā**, 'embracer,' represents δ, ϵ, ζ Hydrae.

8. **Maghā**, 'the bounties,' is the group of stars near Regulus, namely $\alpha, \eta, \gamma, \zeta, \mu, \epsilon$ Leonis.

9. **Pūrvā Phālgunī**, 'bright,' δ and θ Leonis.

10. **Uttarā Phālgunī**, 'bright,' β and 93 Leonis. Since Maghavan and Phalgun are names of Indra, clearly a shifting of the summer solstice due to precession is indicated.

11. **Hasta**, 'hand.' The stars δ, γ, ϵ, α, β in Corvus.

12. **Citrā**, 'bright.' This is Spica or α Virginis.

13. **Svātī**, 'self-bound,' or **Niṣṭyā**, is the Arctutus or α Bootis. The name appears to refer to its nearness to the Saptarṣi, Ursa Major.

14. **Viśākhā**, 'without branches.' The stars α, β, σ Librae. The name refers to the way the ecliptic separates β and σ, with the three stars looking like a bow. In Atharvaveda we encounter the expression *radho viśākhe*, Viśakhā are prosperity.

15. **Anurādhā**, 'propitious,' 'what follows Rādhā.' These are the β, δ, π Scorpii.

16. **Rohiṇī**, 'ruddy', or **Jyeṣṭhā**, 'eldest.' This is Antares, α Scorpii.

17. **Vicṛtau**, 'the two releasers,' or **Mūla**, 'root.' These are the stars from ϵ to λ, ν Scorpii.

18. **Pūrvā Āṣāḍhā**, 'unconquered,' δ, ϵ Sagittarii.

19. **Uttarā Āṣāḍhā**, 'unconquered,' σ, ζ Sagittarii.

20. **Abhijit**, 'reaching victory.' The name refers to a satisfactory completion of the system of nakṣatras. The star is Vega, the brilliant α Lyrae. This is the star that does not occur in the lists which have only 27 nakṣatras on it.

21. **Śroṇā**, 'lame,' or **Śravaṇa**, 'ear.' This represents Altair, α Aquillae, with β below it and γ above it.

22. **Śraviṣṭhā**, 'most famous.' It is the diamond-shaped group α, β, δ, γ Delphini. It was later called **Dhaniṣṭhā**, 'most wealthy.' Perhaps the diamond shape gave the name. Vedāṅga Jyotiṣa says that the winter solstice was in the beginning of Śraviṣṭhā, which indicates a period of around 1350 B.C.E.

23. **Śatabhiṣaj**, 'having a hundred physicians' is λ Aquarii and the stars around it.

24. **Proṣṭhapadā**, 'feet of stool,' are the α, β Pegasi.

25. **Uttare Proṣṭhapadā**, 'feet of stool,' and later **Bhadrapadā**, 'auspicious feet.' These are γ Pegasi and α Andromedae. The name of this and the preceding constellation is suggested by the large square made by these four stars.

26. **Revatī**, 'wealthy,' η, α Piscium.

27. **Aśvayujau**, 'the two horse-harnessers,' are the stars β and α Arietis. **Aśvinī** is a later name. The name refers to the time when these stars rose just before the sun during vernal equinox.

28. **Apabharaṇī**, 'the bearers,' are the 35, 39, 41 Arietis.

Abhijit, the twentieth in the above list, does not occur in the list of the 27 in Taittirīya Saṃhitā or in Vedāṅga Jyotiṣa. Maitrāyaṇī and Kāṭhaka Saṃhitās and 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.

It has been suggested that because the original list of 27 nakṣatras contains only 24 distinct names, these represent the 24 half months of the year. Later, as astronomy developed further, the nakṣatra list was expanded to describe the motions of the moon.

2.1 Nakṣatras and chronology

Motivated by the then-current models of the movements of pre-historic peoples, it became, by the end of the nineteenth century, fashionable in Indological circles to dismiss any early astronomical references in the Vedic literature. But since the publication of *Hamlet's Mill: An essay on myth and the frame of time* by Georgio de Santillana and Hertha von Dechend in 1969 it has come to be generally recognized that ancient myths encode a vast and complex body of astronomical knowledge.[20]The cross-checks provided by the dating of some of the Indian myths provide confirmation to the explicit astronomical evidence related to the nakṣatras that is spelt out below. Other confirmation comes from the archaeological evidence summarized in this article.

The earth's axis of rotation is tipped at an angle of $23\frac{1}{2}^\circ$ with respect to the direction of its orbital motion around the sun. This is what causes the changing seasons because the length of the day keeps on varying. The longest and the shortest days, also called summer and winter solstices, occur roughly near the 21st of June and and 21st December, respectively. The date of a solstice can be marked by noting that around this date the sun appears to linger at the same extreme at dawn. The days when the days and nights are equal are called 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° 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.

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. Polaris (α Ursae Minoris) is the Pole star now but around 3000 B.C.E. it was α Draconis which was followed later by β Ursae Minoris; in C.E. 14000 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 B.C.E. 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.

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 yamanakṣatras (yama: twin, dual). This classification in Taittirīya

Brāhmaṇa (1.5.2.7) corresponds to 2300 B.C.E.

As mentioned above, the list beginning with Kṛttikā indicates that it was drawn up in the third millennium B.C.E. The legend of the cutting off of Prajāpati's head suggests a time when the year began with Mṛgaśīrṣa in the fifth millennium B.C.E. Scholars have also argued that a subsequent list began with Rohiṇī. This view is strengthened by the fact that there are two Rohiṇīs, separated by fourteen nakṣatras, indicating that the two marked the beginning of the two half-years.

Śatapatha Brāhmaṇa speaks[21] of a marriage between the Seven Sages, the stars of the Ursa Major, and the Kṛttikās; this is elaborated in the Purāṇas where it is stated that the ṛṣis remain for a hundred years in each nakṣatra. In other words, during the earliest times in India there existed a centennial calendar with a cycle of 2,700 years. Called the Saptarṣi calendar, it is still in use in several parts of India. Its current beginning is taken to be 3076 B.C.E. On the other hand, notices by the Greek historians Pliny and Arrian suggest that, during the Mauryan times, the calendar used in India began in 6676 B.C.E. It is very likely that this calendar was the Saptarṣi calendar with a beginning at 6676 B.C.E.[22]

Around 500 C.E., a major review of the Indian calendar was attempted by astronomers. Āryabhaṭa, Varāhamihira and others used the nakṣatra references that the Saptarṣi were in Maghā at the time of the Mahābhārata war to determine its epoch. Āryabhaṭa declared the war to have occurred in 3137 B.C. (the Kaliyuga era begins 35 years after the war), and Varāhamihira assigned it 2449 B.C.E. It has been suggested that this discrepancy arose because the change in the number of nakṣatras from the earlier counts of 27 to the later 28 was differently computed by the two astronomers. It is quite likely that the fame of the Kaliyuga era with its beginning assigned to 3102 B.C.E. prompted a change in the beginning of the Saptarṣi era to about the same time, viz. to 3076 B.C.E.

The shifting of seasons through the year and the shifting of the northern axis allow us to date several other statements in the books.[23] Thus the 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. This correspond to 2950 B.C.E.

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. This indicates 1660 B.C.E.

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 1370 B.C.E.

It should be noted that these dates can only be considered to be very approximate. Furthermore, these dates do not imply that the texts come from the corresponding period; the text may recall an old tradition. A chronology of the Vedic period by means of astronomical references was attempted by the historian of science P.C. Sengupta.[24] Amongst other evidence, Sengupta uses the description of the solar eclipse in RV 5.40.5-9 to fix a date for it. Unfortunately, this work has not received the attention it deserves.

The changes in the beginning of the Nakṣatra lists bring us down to the Common Era; at the time of Varāhamihira (550 C.E.) the vernal equinox was in Aśviní.

3 Ritual, geometry and astronomy

We have mentioned that the altars used in the ritual were based on astronomical numbers related to the reconciliation of the lunar and solar years. The fire altars symbolized the universe and there were three types of altars representing the earth, the space and the sky. The altar for the earth was drawn as circular whereas the sky (or heaven) altar was drawn as square. The geometric problems of circulature of a square and that of squaring a circle are a result of equating the earth and the sky altars. As we know these problems are among the earliest considered in ancient geometry.

The fire altars were surrounded by 360 enclosing stones, of these 21 were around the earth altar, 78 around the space altar and 261 around the sky altar. In other words, the earth, the space, and the sky are symbolically assigned the numbers 21, 78, and 261. Considering the earth/cosmos dichotomy, the two numbers are 21 and 339 since cosmos includes the space and the sky.

The main altar was built in five layers. The basic square shape was modified to several forms, such as falcon and turtle (Figure 2). These altars were built in five layers, of a thousand bricks of specified shapes. The construction of these altars required the solution to several geometric and algebraic problems.

Two different kinds of bricks were used: the special and the ordinary.

The total number of the special bricks used was 396, explained as 360 days of the year and the additional 36 days of the intercalary month. By layers[25], the first has 98, the second has 41, the third has 71, the fourth has 47 and the fifth has 138. The sum of the bricks in the fourth and the fifth layers equals 186 tithis of 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, and the number of bricks in the third layer equals the integer nearest to one fifth of the number of days in the lunar year, and so on.

The number of ordinary bricks equals 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.

3.1 Equivalence by area

The main altar was an area of $7\frac{1}{2}$ units. This area was taken to be equivalent to the nominal year of 360 days. Now, each subsequent year, the shape was to be reproduced with the area increased by one unit.

The ancient Indians spoke of two kinds of day counts: the solar day, and tithi, whose mean value is the lunar year divided into 360 parts. They also considered three different years: (1) nakṣatra, or a year of 324 days (sometimes 324 tithis) obtained by considering 12 months of 27 days each, where this 27 is the ideal number of days in a lunar month; (2) lunar, which is a fraction more than 354 days (360 tithis); and (3) solar, which is in excess of 365 days (between 371 and 372 tithis). A well-known altar ritual says that altars should be constructed in a sequence of 95, with progressively increasing areas. The increase in the area, by one unit yearly, in building progressively larger fire altars is 48 tithis which is about equal to the intercalation required to make the nakṣatra year in tithis equal to the solar year in tithis. But there is a residual excess which in 95 years adds up to 89 tithis; it appears that after this period such a correction was made. The 95 year cycle corresponds to the tropical year being equal to 365.24675 days. The cycles needed to harmonize various motions led to the concept of increasing periods and world ages.

3.2 The Ṛgvedic altar

The number of syllables in the Ṛgveda confirms the textual references that the book was to represent a symbolic altar. According to various early texts,[26] the number of syllables in the Ṛgveda is 432,000, which is the number of muhūrtas in forty years. In reality the syllable count is somewhat less because certain syllables are supposed to be left unspoken.

The verse count of the Ṛgveda can be viewed as the number of sky days in forty years or $261 \times 40 = 10,440$, and the verse count of all the Vedas[27] is $261 \times 78 = 20,358$.

The Ṛgveda is divided into ten books with a total of 1,017 hymns which are placed into 216 groups. Are these numbers accidental or is there a deliberate plan behind the choice? One would expect that if the Ṛgveda is considered akin to the five-layered altar described in the Brāhmaṇas then the first two books should correspond to the space intermediate to the earth and the sky. Now the number that represents space is 78. When used with the multiplier of 3 for the three worlds, this yields a total of 234 hymns which is indeed the number of hymns in these two books. One may represent the Ṛgvedic books as a five-layered altar of books as shown in Table 1.

Table 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 2.

Table 2: Hymns in the altar of books

191	114
104	92
87	75
62	58
43	191

The choice of this arrangement is prompted by the considerable regularity in the hymn counts. Thus 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. 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.

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

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 339×3. 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.

Consider the two numbers 1017 and 216. One can argue that another parallel with the representation of the layered altar was at work in the group total of 216. Since the Ṛgvedic 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.

Consider now 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. If the number 108 was taken to represent symbolically the distance between the earth and the sky, the question arises as to why it was done. The answer is apparent if one considers the actual distances of 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 marvellous coincidence that the angular size of the sun and the moon, viewed from the earth, is about identical.

It is easy to compute 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 27×4, because of the mapping of the sky into 27 nakṣatras.

The second number 339 is simply the number of disks of the sun or the moon to measure the path across the sky: $\pi \times 108 \approx 339$.

We return to a further examination of the numbers 296, 339, and 382 in the design of the Ṛgvedic altar. It has been suggested that 339 has an obvious significance as the number of sun-steps during the average day or the equinox, and the other numbers are likely to have a similar significance. In other words, 296 is the number of sun-steps during the winter solstice and 382 is the number of sun-steps during the summer solstice.

There also exists compelling evidence, of a probabilistic sense, that the periods of the planets had been obtained and used in the setting up of the Ṛgvedic astronomical code.[28]

4 The motions of the sun and the moon

Vedāṅga Jyotiṣa (VJ), the text that describes some of the astronomical knowledge of the times of altar ritual, has an internal date of c. 1350 B.C., 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 book assumes great importance in the understanding of the earliest astronomy.

VJ describes the mean motions of the sun and the moon. This 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. As the only extant astronomical text from the Vedic period, we describe its contents in some detail.

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

Furthermore, 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[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 travelled 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).

> The moon is conjoined with each asterism 67 times during a yuga. The sun stays in each asterism $13\frac{5}{9}$ days.

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 hours and 50.4864 minutes.

4.1 Computation of tithis, nakṣatras, kalās

Although a mean tithi is obtained by considering the lunar year to equal 360 tithis, the determination of a tithi each day is by a calculation of a shift of the moon by 12° with respect to the sun. In other words, in 30 tithis it will cover 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 a mean tithi is defined by a formula. VJ takes it to be 122 parts of the day divided into 124 parts.

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. 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 the earlier section, 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.

4.2 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. But it is clear that the use of mean motions can lead to discrepancies that need to be corrected at the end of the yuga.

The framework of VJ has approximations built into it such as 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 5×10^{-4}. This leads to an error of less than a day in a yuga of five years.

The constructions of the geometric altars as well as the Vedic books that come centuries before VJ confirm that the Vedic Indians knew that the year was more than 365 days and less than 366 days. The five year period of 1,830 days, rather than the more accurate 1,826 days, was chosen because it is divisible by 61. This choice defines a symmetry with the definition of the tithi as $\frac{61}{62}$ of the day. The VJ system was thus very accurate for the motions of the moon but it could have only served as a framework for the motions of the sun. 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.

Mean motion astronomy can lead to significant discrepancy between true and computed values. The system of intercalary months introduced further irregularity into the system. This means that 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.

Since the Vedic astronomers were evidently aware of the many corrections that is required in the calendric system of the VJ, one might wonder about the choice of its constants. It appears that the yuga of 1,830 days, rather than the more accurate 1,826 days, was chosen because it is divisible by 61; this choice simplifies computations for a tithi defined as $\frac{61}{62}$ of the day.

5 The calendar and biological periods

The stars in the sky were pictured as belonging to the figure of a cosmic man. This metaphor represents relationships in the universe across scales. It appears that the actual connection between stars and living beings was based on the identity between basic biological rhythms and astronomical periods.

With the central role given to the notion of equivalence between the microcosm and the macrocosm, it is natural to assume that the Vedic people had found many connections between biological and astronomical processes.

The most fundamental biological rhythms are matched to the periods of the sun or the moon.

For example, fiddler crabs, in their natural habitat on the shore, burrow themselves during high-tide, emerging when the tide recedes to feed, mate, and challenge each other. When these crabs are removed to the laboratory and held in an incubator with constant conditions, they still run around in their containers during the time of each low tide. According to J.D. Palmer, "So accurate are their responses that the students working in the lab use the crab behavior patterns, rather than the tide tables of the Geodetic Survey, to plan their field trips to the crab's old home 30 miles across Cape Cod... How do crabs do it? It is not yet known."[30]

In humans the menstrual period has by tradition been taken to correspond to the moon's motion; in fact "menses" means lunar month. New research supports this:

> In a study of a number of women with variable onset of menstrual periods, artificial illumination of the bedroom through the 14th to 17th nights following the onset of menstruation resulted in the regularization of the period, with the period length coming very close to 29.5 days, the natural synodic month. That this period is a biologically significant one for the human species is further suggested by the fact that the average duration of pregnancy (from ovulation to birth) in the human is rather precisely nine 29.53 synodic months. *Encyclopaedia Britannica* (1994; Macropaedia article on Animal Behaviour, p. 761)

One should note the distinction between lunar and freerunning circalunar cycles. A lunar cycle is in step with the motions of the moon. The menstrual cycle is a freerunning cycle with the same period as that of the moon. One might assume that entrainment to the lunar cycle was triggered by moonlight. In the living under artificial lights of modern times it is easy to see how the direct correlation with the moon's motion has been lost.

It has been a surprise[31] that the fundamental circadian rhythm inside us is not the 24-hour one related to the motion of the sun but rather the 24 hour 50 minute one according to the period of the moon, since each moonrise is 50 minutes later than the preceding one. We share this approximately 24-hour-50-minute clock with monkeys and other non-humans.

This 24-hour-50-minute clock was discovered by the moderns only about 30 years ago in experiments on a blind squirrel monkey. The activity of this monkey were recorded night and day for a period of three years and it was discovered that her rhythms drifted later each day by an average of about 46 minutes. Was the deficit of four minutes from the moonrise period due to the reference with respect to the stars, we do not know. The monkey kept her own time, unaffected by the activities around her.

That this connection might have been known in the ancient world is suggested by the fact that the moon (Soma) is called the "lord of speech" (Vācaspati) in the Ṛgveda (RV 9.26.4; 9.101.5). It is taken to awaken eager thoughts (RV 6.47.3). Many references connect the moon with the mind. This is stated most directly in the Śatapatha Brāhmaṇa 8.1.2.7 as the slogan: "the mind is the moon."

Fire, having become speech, entered the mouth
Air, becoming scent, entered the nostrils
The sun, becoming sight, entered the eyes
The regions becoming hearing, entered the ears
The plants, becoming hairs, entered the skin
The moon, having become mind, entered the heart.
—*AA 2.4.2.4*

This verse from the Āraṇyaka period speaks at many levels. At the literal level there is an association of the elements with various cognitive centers. At another level, the verse connects the time evolution of the external object to the cognitive center.

Fire represents consciousness and this ebbs and flows with a daily rhythm. Air represents seasons so here the rhythm is longer. The sun and sight have a 24-hour cycle. The regions denote other motions in the skies so hearing manifests cycles that are connected to the planets. The plants have daily and annual periods; the hairs of the body have an annual period. The mind has a period of 24 hours and 50 minutes like that of the moon.

6 The planets

Although it is certain that the planets had been studied by the Ṛgvedic people, we do not find a single place in the texts where the names are listed together. The list below brings together some of the names, together with the ascribed colours, used in a variety of places including the later Purāṇic literature.

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

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

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

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

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

There is one other name that is not well attested, namely Vena for Venus. 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 implies that Mercury was first noted during the era of 3400-2210 B.C.E. when the vernal equinox was in the Pleiades.

Jaiminigṛhyasūtra[32]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 colours 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 centre at the 366-day solar year.

6.1 On 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 youger 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.

Now what do these steps mean? According to late tradition, Viṣṇu is a solar deity and so 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.

But both of these interpretations appear unsatisfactory. Neither of these interpretations squares with the special significance attached to the third step. Nor does not explain the putative identity of Mercury and Viṣṇu.

An explanation becomes obvious when we consider the Vedic altar ritual. It appears likely 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 will be 87 days. Furthermore, three synodic periods of Mercury, at 118 days a period, equal the 354 lunar days or 360 tithis. It appears that this dual relationship led to the great importance being given to the myth of the three steps of Viṣṇu. Of course, the figures for the periods are only approximate but as expected at the first determination of these numbers an attempt was made to connect them to the basic numbers of 261 and 354.

The explicit name of Budha for Mercury appears in Pañcaviṃśa Brāhmaṇa (PB) which is dated definitely after 1900 B.C.E. 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 note 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 acccounts describe the planets in relation to each other. Our arguments showing that the period of Mercury was obtained in the third millennium B.C.E. imply that as the determination of the period of Mercury is the hardest amongst the classical planets, the periods of the other planets had been obtained.

The literature that followed the Ṛgvedic age was at first concerned more with the ritual related to the earlier astronomy of the Vedic age. Once the planetary system fell into place, the gods became supernumeraries. Now the focus shifted to their duals that inhabit the inner universe. Thus by the time of the Śatapatha Brāhmaṇa (second millennium B.C.E.), the original stars of the Ursa Major were identified with the cognitive centres in the brain as in ŚB 8.1 or in more detail in BU 2.2.4.

The Ṛgveda and the Śatapatha Brāhmaṇa speak of the five planets as gods. There is also a mention of the thirty-four lights, which appear to be the twenty seven nakṣatras, the five planets, the sun and the moon. The moon is the fastest moving of the heavenly bodies, and so it is compared to the male who activates or fertilizes the other heavenly bodies with which it comes in contact. The Ṛgveda speaks of the five bulls of heaven, which appear to be the five planets. Being faster than the fixed stars, the planets can, in turn, be compared to bulls.

Taittirīya Saṃhitā[33]speaks of the 33 daughters of Prajāpati, personification of time here, that are given in marriage to Soma, the moon, viewed as king. These are the 27 nakṣatras, the five planets, and the sun. The sun as the bride, Sūryā, is described in the Ṛgveda and the Atharvaveda.

Since the planets move through the nakṣatras and Venus and Jupiter are brighter than any of the stars, observation of the nakṣatras presupposes a notice of the planets. The Vedāṅga Jyotiṣa does not mention the planets, but that is so because its concern is only the motions of the sun and the moon related to fixing the calendar.

The rivalry between the families of Aṅgirases and the Bhṛgus, mythical figures in the Ṛgveda, represents the motions of Jupiter and Venus. This is clear in later accounts where Bṛhaspati (Jupiter), the priest of the gods because its motion is closest to the ecliptic, is an Āṅgiras and Kavi Uśanas or Śukra (Venus), a Bhārgava, is the priest of the Asuras.

The idea of eclipse was expressed by the notion of Rāhu seizing the heavenly body. The fact that graha, 'seize,' is the name used for planets right from the time of Atharvaveda[34]suggests that the waxing and waning of the two inferior planets, Mercury and Venus, as well as the change in the intensity of the others was known.

Although there is mention of a week of six days, called a ṣaḍaha, in the early books, it does not follow that the tradition of a week of seven days is a later one. The seven day week was in use during the time of Atharva Jyotiṣa.

The sidereal periods suggested by the astronomical code in the organization of the Ṛgveda are:[35]

Mercury: 87 days
Venus: 225 days
Mars: 687 days
Jupiter: 4,340 or 4,350 days
Saturn: 10,816 days.

6.2 Soma

Soma, or the moon, is one of the most important deities of the Ṛgveda. It is related to Sūrya the way puruṣa is related to prakṛti. Soma is almost always the moon in the ninth book of the Ṛgveda. That very few Western scholars of the nineteenth century recognized this fact can only be explained by recalling the incorrect assumptions they laboured under. Soma, as a drink, was meant to celebrate the creative function of the moon as reflected in the tides, the menstrual cycle and the growth of plants.

7 The Yuga concept

There are allusions to yugas, meant as an age, in the Vedas. In the Aitreya Brāhmaṇa[36]Kali, Dvāpara, Tretā, and Kṛta are compared to a man lying down, moving, rising, and walking. Ṣaḍviṃśa Brāhmaṇa[37]mentions the four ages Puṣya, Dvāpara, Khārvā, and Kṛta. In order from Kṛta to Kali, each yuga represents a decline in morality, piety, strength, knowledge, truthfulness, and happiness. The notion of a yuga appears to have a historical basis. If we accept that a catastrophic tectonic event took place around 1900 B.C.E., leading eventually to a great shift in the population away from the Sarasvatī valleys, then Kaliyuga could be a memory of the beginning of that dark age. Support for this view comes from the Mahābharata, according to which all places were sacred in the Kṛtayuga; Puṣkara in the Sarasvatī region was the most sacred in Tretāyuga; Kurukṣetra in Dvāpara; and Prayāga at the junction of Gaṅgā and Yamuna in the Kaliyuga. This clearly marks the shift in focus of the Vedic people.

The five years of the yuga of the Vedāṅga Jyotiṣa are named variously; one text calling them saṃvatsara, parivatsara, idāvatsara, iduvatsara, and vatsara. It has been suggested that the 33 gods mentioned at many places refer to a cycle of 33 years but this cannot be accepted until corroborative evidence is found. As mentioned before, a cycle of 95 years is described in Śatapatha Brāhmaṇa. The yuga of 60 years appears to have emerged out of an attempt to harmonize the approximate sidereal periods of 12 and 30 years for Jupiter and Saturn, respectively. Consideration of more accurate sidereal values requires much larger periods that are seen in the later Siddhāntic astronomy of the Classical period.[38]

The Purāṇas talk of a kalpa, a day of Brahmā which is taken to equal 12,000 thousands of divine years, each of which equals 360 human years, for a total of 4,320 million human years. Kṛta, Tretā, Dvāpara, and Kali are supposed to last 4,000, 3,000, 2,000, 1,000 divine years respectively. In addition, there are sandhyās (twilights) of 800 (two twilights of 400 years), 600, 400, 200 on the yugas, in order, to give a total span of 12,000 divine years. Brahmā, the creator of time, is a personification of the beginning of the sustaining principle, to be taken either as Viṣṇu or Śiva. Each day of Brahmā is followed by a night of the same duration. A year of Brahmā equals such 360 day and nights, and the duration of the universe is the span of 100 Brahmā years. The largest cycle is 311,040,000 million years. We are supposed to be in the 55th year of the current Brahmā. The large cycle is nested in still larger cycles. Within each kalpa are fourteen secondary cycles, called manvantaras, each lasting 306,720,000 years. In each manvantara, humans begin with a new Manu. We are now in the seventh manvantara of the kalpa, started by Manu Vaivasvata.

A kalpa equals a thousand mahāyugas, each of which has the four yugas Kṛta, Tretā, Dvāpara, and Kali. Each manvantara may be divided into 71 mahāyugas. While the yugas, as defined in the Purāṇic literature of the first millennium C.E. have extremely large periods in multiples of the 'years of the gods,' it is likely that the four yugas were originally 4,800, 3,600, 2,400, and 1,200 ordinary years, respectively.

8 Physics, psychology, medicine

Once one sees that the Vedic knowledge was defined in a recursive fashion, it becomes easy to see Vedānta, tantra and yoga, as well as Vedic ritual as different aspects of this system. One noteworthy equivalence is between the 72,000 nāḍīs in the human body and one third the number of muhūrtas in twenty years; another is that of the 21 organs in the middle body and the number signifying the earth. At other times the equivalences were more metaphorical. The eyes are the sun and the moon, likewise one can speak of the planets (graha) inside the body; nevertheless, here a numerical connection in terms of planet periods and body processes might have been meant.

One may speculate that the catastrophe of the drying up of the Sarasvatī river was such a major disruption so that the system of knowledge representation using altar designs fell into disuse. This is supported by the fact that the altars required an urban setting owing to the need of precise bricks of different sizes. The transition from the erstwhile urban to the new rural settings in the newly settled regions to the east beyond the Gaṅgā is represented by the Āraṇyaka phase of the Vedic literature and it is also alluded to in the Brāhmaṇas. It was during this phase that the altar ritual lost its link with astronomy and was transformed. Thus agnihotra was replaced by prāṇa-agnihotra. Later developments focused on the inner space of the individual. The fires of the altar have the parallel in the fires inside the body. A sacrifice, yajña, is a recursive system: any given level is based on a transcendence of the lower level. This is to be seen not only in life but also within the mind, which was viewed as a hierarchical system with systems of the the gross body, prāṇa, manas, vijñāna, and ānanda.

In analysis a dynamic balance between three fundamental categories was postulated. Śvetāśvatara Upaniṣad[39]speaks of a balance between red, white, and black made conscious by puruṣa; this is repeated in the rajas, sattva, and tamas of prakṛti in Sāṅkhya. Clearly, the regions of atmosphere, sky, and earth correspond to these three. In Vedic society also there is mention of an original single class that divided into the three brāhmaṇa, rājanya, and vaiśya. The altars are made in five layers to represent the three regions and the two intermediate spaces where atmosphere and earth and also atmosphere and sky meet. Paralleling this later a fourth class of śūdra was added to the societal classes to represent the new "foundation" against which the other classes were defined; the fifth class of "sages", who transcended class categories, was described only indirectly. The texts themselves do not speak with this directness about the parallels but these are easy enough to infer.

Bṛhadāraṇyaka Upaniṣad[40]speaks of three primary constituents. Later like the expansion of the altar from three to five layers, we come across five primary elements, pancabhūtas, earth, water, fire, air, and ether. The three dośas or dhātus (humors) vāta, pitta, and kapha in the human body likewise define a basic tripartite model. But each of these dhātus is taken to have five types.

The observer has a central place in Indian thought, and a consideration of the act of observation leads to the question of the nature of time. This question eventually leads to a consideration of consciousness and the self. But as the basic science of time, astronomy helps us place the overarching system of knowledge of Vedic times in context.

Abbreviations

AA	Aitareya Āraṇyaka
AB	Aitareya Brāhmaṇa
ASS	Āpastamba Śulbasūtra
AV	Atharvaveda
BSS	Baudhāyana Śulbasūtra
BU	Bṛhadāraṇyaka Upaniṣad
CU	Chāndogya Upaniṣad
KB	Kauṣītaki Brahmaṇa
PB	Pañcaviṃśa Brahmaṇa
RV	Ṛgveda
ŚB	Śatapatha Brāhmaṇa
ŚU	Śvetāśvatara Upaniṣad
TB	Taittirīya Brāhmaṇa
TS	Taittirīya Saṃhitā
VJ	Vedāṅga Jyotiṣa

Notes

1. See, for example, RV 1.25.8. This is described in many passages in other texts such as Kauṣītaki Brahmaṇa and Śatapatha Brāhmaṇa. Specifically the thirteenth intercalary month is mentioned in KB 5.8, 7.10, 19.2, 25.11 and ŚB 5.4.5.23, 6.2.2.29, 9.1.1.43, 12.8.2.31. For detailed references and a general background to this article see S.C. Kak, *The Astronomical Code of the Ṛgveda.* Aditya, New Delhi, 1994.

2. RV 1.164.45.

3. ŚB 11.5.8 or AB 5.32.

4. Although such a technical usage of psychological categories comes later in Sāṅkhya, references in CU 6.4 and ŚU 4.5 make it abundantly clear that these categories are quite old.

5. S.C. Kak, "Astronomy of the Vedic Altars and the Rigveda", *Mankind Quarterly*, 33, 43-55, 1992; S.C. Kak, "Astronomy of the Vedic Altars", *Vistas in Astronomy,* 36, 117-140, 1993 and so on. For a detailed bibliography see S.C. Kak, *The Astronomical Code of the Ṛgveda.*

6. RV 1.164.2 speaks of *eko aśvo vahati saptanāmā*; Nirukta 4.27 makes it clear that this horse is the sun; ŚB 6.1.11 speaks of the birth from Prajāpati, representing time here, of aśva before that of the earth.

7. BSS 7.17, ASS 14.11. For the texts see S.N. Sen and A.K. Bag, *The Śulbasūtras.* Indian National Science Academy, New Delhi, 1983. The significance of its mathematics is described in A. Seidenberg, "The origin of mathematics," *Archive for History of Exact Sciences*, 18, 301-342, 1978.

8. J. Gonda, *The Ritual Sutras.* Otto Harrassowitz, Wiesbaden, 1977. That the ritual had its own grammar is described in F. Staal, *Rules Without Meaning: Ritual, Mantras and the Human Sciences.* Peter Lang, New York, 1989.

9. ŚB 10.4.3.9.

10. ŚB 7.1.1.13 for earth, ŚB 7.1.2.12 for space, and ŚB 8.2.1,2 for sky or heaven.

11. F.E. Pargiter, *Ancient Indian Historical Tradition.* Oxford University Press, London, 1922.

12. B.G. Tilak, *The Orion.* Tilak Brothers, Pune, 1893; M. Winternitz, *A History of Indian Literature.* University of Calcutta, 1927; reprint Delhi, 1972.

13. S.C. Kak, "The Indus tradition and the Indo-Aryans," *Mankind Quarterly*, 32, 195-213, 1992; J.G. Shaffer, "The Indus valley, Baluchistan, and Helmand traditions: neolithic through bronze age," in J. Ehrlich (ed.), *Chronologies in Old World Archaeology (3rd Edition).* Chicago University Press, Chicago, 1992. See also G. Feuerstein, S.C. Kak, and D. Frawley, *In Search of the Cradle of Civilization: New Light on Ancient India*. Quest Books, Wheaton, IL, 1995.

14. H.P. Francfort, "Evidence for Harappan irrigation system in Haryana and Rajasthan," *Eastern Anthropologist*, 45, 87-103, 1992.

15. PB 25.10.16. This also fixes this Brāhmaṇa as posterior to 1900 B.C.E.

16. Some scholars have contested the identification of Vena with Venus.

17. ŚB 2.1.2.18-19; see also Nirukta 3.20.

18. V. Vidyālaṅkāra, *Śatapatha Brāhmaṇastha Agnicayana Samīkṣā.* Bahalgarh, 1985.

19. TB 1.5.2.7

20. G. de Santillana and H. von Dechend, *Hamlet's Mill: An essay on myth and the frame of time.* Gambit, Boston, 1969.

21. ŚB 2.1.2.4-5.

22. S.C. Kak, *The Astronomical Code of the Ṛgveda.*

23. T.S. Kuppanna Sastry, *Vedāṅga Jyotiṣa of Lagadha.* Indian National Science Academy, New Delhi, 1985.

24. P.C. Sengupta, *Ancient Indian Chronology.* University of Calcutta Press, Calcutta, 1947.

25. ŚB 10.4.3.14-20.

26. ŚB 10.4.2.23-24.

27. S.P. Sarasvati and S. Vidyalankara, *Ṛgveda Saṃhitā.* Veda Pratishthana, Delhi, 1987.

28. S.C. Kak, *The Astronomical Code of the Ṛgveda.*

29. T.S. Kuppanna Sastry, *Vedāṅga Jyotiṣa of Lagadha.* See also S.C. Kak, "The astronomy of the age of geometric altars," *Quarterly Journal of the Royal Astronomical Society,* 36, 385-396, 1995.

30. J.D. Palmer, *An Introduction to Biological Rhythms.* Academic Press, New York, 1976.

31. A.T. Winfree, *The Timing of Biological Clocks.* Scientific American Books, New York, 1987.

32. W. Caland (tr.), *The Jaiminigṛhyasūtra.* Motilal Banarsidass, 1984.

33. TS 2.3.5.

34. AV 19.9.7-10.

35. S.C. Kak, "The astronomical code of the Rigveda," *Current Science*, 66, 323-326, 1994.

36. AB 7.15.4.

37. ṢB 5.6.

38. R. Billard, *L'astronomie Indienne.* Paris, 1971.

39. ŚU 4.5.

40. BU 1.2.2.

Figure 1. The Plan of the Altars.
Figure 2. A variant of śyenacit, the falcon altar.