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ASTRONOMY OF THE VEDIC ALTARS

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Abstract

In this paper, two ancient Indian texts, the *Śatapatha Brāhmana* and the *Rigveda*, are examined for their astronomical content. It is argued that the 95 year ritual of *agnicayana* had an astronomical basis, which implies a knowledge of the length of the tropical year being equal to 365.24675 days. An astronomical code has been discovered in the structure of the *Rigveda*, which has been partially deciphered. This code expressed the knowledge that the sun and the moon are about 108 times their respective diameters away from the earth. This analysis leads to a major revision of our understanding of the history of ancient astronomy.

I. Introduction

The concept of equivalence played a central role in the Vedic system of knowledge (*e.g.*, Smith 1989, Heesterman 1991). According to this concept the elements of the macrocosmos and the microcosmos are related; the Vedic fire altar was used to show these equivalences symbolically. This implies that astronomical knowledge might have been represented in the design of these altars. That this is so is described in a cryptic form in the 10th chapter of *Śatapatha Brāhmana* which is entitled *Agnirahasya* ("Secrets of the Year"). However, this basis has not been yet studied systematically. The astronomy of these altars will be analyzed in this paper. I will also show how corroborative evidence for this analysis is provided by the *Rigveda*, which itself can be viewed as a symbolic altar.

Geometry and mathematics of the *Śatapatha Brāhmana* and the *Śulbasūtras* (*e.g.*, Seidenberg 1962, 1978, 1983) are generally considered the description of the earliest science in India. Seidenberg has argued that the philosophy that equivalent altars were to have equal areas led to the posing of basic problems of geometry leading to results such as the theorem of the diagonal. He also marshals reasons why this is likely to have been known at the time of *Taittirīya Samhitā* itself. A conservative chronology places the final form of the *Śatapatha Brāhmana* to 1000-800 B.C.E. and that of the *Taittirīya Samhitā* to 1000 B.C.E. (Renou and Filliozat 1947). On the other hand, it is accepted that the myths described in the *Vedas* and the *Brāhmanas* deal with astronomical events of the 4th millennium B.C.E. and earlier (Santillana and Dechend 1969, Kramrisch 1981). New results in archaeology are compelling a revision of the conservative chronology of the Vedic literature and it is likely that the actual epochs for these books are closer to the much earlier traditional chronology (Frawley 1991, Kak 1992a, Roy 1982). Of the traditional accounts, the *Purānas* present the most conservative date for the Mahābhārata war which, in the generally accepted readings, implies a date of about 1500 B.C.E. for the *Śatapatha Brāhmana*. However, there is an inherent ambiguity in the Purānic statements (Pargiter 1913, Pargiter 1922, Mitchiner 1982): the Purānic statements could be referring to an epoch of about 2400 B.C.E. On the other hand, the statement in ŚB 2.1.2.3 that the *Krittikās* never swerve from the east has been interpreted to refer to the epoch of c. 2950 B.C.E.

Seidenberg argues how the knowledge in the *Śulbasūtras* represents a tradition that goes back to pre-1700 B.C.E. New theories on ancient Indian chronology accept the presence of the Indo-Aryans in India in the 3rd millennium B.C.E. and earlier which is in consonance with Seidenberg's framework (Kak 1987b, Kak 1992a). Specifically, the hydrological evidence that indicates that the Sarasvatī river, the pre-eminent river of the Vedic era, dried up around 1900 B.C.E. (Kenoyer 1991) makes this epoch the *terminus ad quem* for the early Vedic age. However, we will not consider here the issues raised by the new archaeological discoveries regarding the chronology of the Vedic literature.

Astronomical knowledge in the *Śatapatha Brāhmana* and the *Vedas* (Kak 1992b, Kak 1993) can help us date the evolution of astronomy in India. The earliest texts devoted purely to astronomy in India are the two recensions, the *Rik* (R-VJ) and the *Yājusha* (Y-VJ), of the *Vedānga Jyotisha*. Two noteworthy discussions of the contents of the *Vedānga Jyotisha*s are contained in the books by Sastry (1985) and Holay (1990). Sastry ascribes the R-VJ to either 1150 B.C.E. or 1370 B.C.E. whereas Holay ascribes it to 2884 B.C.E. There are others who assign a much lower date of 500 B.C.E. to R-VJ (*e.g.*, Pingree 1973). However, the framework which is used to argue this late date was based on the belief that there was no tradition of observational astronomy in India which has been shown by Billard (1971) to have been incorrect. Nevertheless, owing to the difference of opinions on the development of Indian science, many histories of astronomy have ignored the Vedic contributions (*e.g.*, van der Waerden 1974). Just as the *Śatapatha Brāhmana*

was not examined for its geometrical contents until Seidenberg's research, it has not been examined for its astronomical content. No doubt this neglect is due to the prejudice that the 19th century European scholars had against the *Brāhmanas* due to a misunderstanding of the contents. This prejudice that plagued Indological studies for almost a century has been summarized well by O'Flaherty (1985). Likewise, Gonda (1984) stresses the unreliability of the earlier theories of European scholars related to *Prajāpati* and the year as sketched in the *Brāhmanas*. Gonda brings together references from various texts, but he does not provide any astronomical analysis.

In this article we argue the thesis that the philosophy of equivalence, pointed out by Seidenberg in his discussion of the *Śatapatha Brāhmana*, extended to number and to structure and this allows us to see several Vedic texts before the *Śulbasūtras* in a new light. This philosophy was instrumental in the discovery of geometrical laws. Specifically, the development of the scientific method in India in that age was inspired by some rough parallels between the physical universe and man's physiology. This led to the notion that if one could understand man fully, that would eventually lead to the understanding of the universe. It is important to note here that a belief that the universe is knowable had to precede the development of any empirical inquiry into the nature of that knowledge. This led to a style of seeking metaphors to describe the unknown which is the first step in the development of a scientific theory. A philosophy of the scientific method is already sketched in the *Rigveda* (Kak 1986). According to the Rigvedic sages nature has immutable laws and it is knowable by the mind although all representations of it in rational terms lead to paradox. We will describe the observational framework that is likely to have led to the development of this philosophy.

Many Vedic rites went on for the full year and they were clearly meant to mark the passage of time. A considerable part of the *Śatapatha Brāhamana* deals with altar construction in the *agnicayana* rite. Since *Agni* is the year, therefore this rite is about a representation of the reckonings of the year. This twelve-day *agnicayana* rite 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 *prācīnavamśa* or *prāgvamśa*. It is generally accepted that the measures in the *Brāhmanas* are the same as in the *Śulbasūtras* (Sen and Bag 1983). The important ones for our purposes are:

1 prādeśa = 12 aṅgulas
1 pada = 15 aṅgulas
1 prakrama = 2 padas
1 purusha = 5 aratnis = 120 aṅgulas

The unit of *pada* (foot) is sometimes taken to be smaller, being either 10 or 12 *aṅgulas*.

The *mahāvedi* trapezium measures 30 *prakrama* on the west, 24 *prakrama* on the east, and 36 *prakrama* lengthwise. The choice of these numbers appears to have been related to the sum of these three equalling one fourth of the year or 90 days (ŚB 10.2.3.4).

The nominal year of 360 days was used to reconcile the discrepancies between the lunar and solar calendars, both of which appear to have been in use. In the *mahāvedi* there is built a brick altar 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 *dakshināgni*. The *dakshināgni* is also called the *anvāhāryapacana*, *i.e.*, where cooking is done. In addition eight *dhishnya* hearths are built (Figure 1; Dh - *Dhishnya* hearths which include Āg - *Āgnīdhra* and M - *Mārjālīya*).

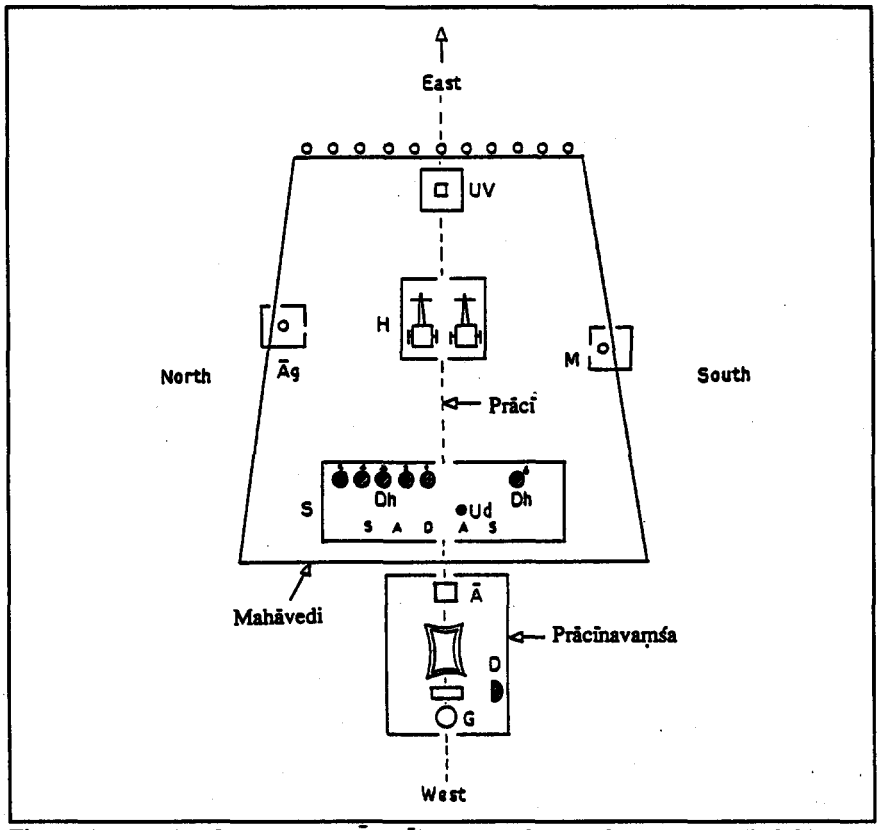

Figure 1. The plan for the altars: Ā - *Āhavanīya*; G - *Gārhapatya*; D - *Dakshināgni*; UV - *Uttaravedi*; H - *Havirdhāna* shed.

Agnicayana altars are supposed to symbolize the universe. *Gārhapatya* represents the earth (ŚB 7.1.1.13), the *dhishnya* hearths represent space (ŚB 7.1.2.12), and the *āhavanīya* altar represents sky (ŚB 8.2.1,2). 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. *Śatapatha Brāhmana* (ŚB 10.4.3.9) declares that knowledge is represented through altar construction in *agnicayana*.

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 *vasant*, the body as *hemanta* and *śiśira*, the two wings as *śarad* and *grīshma*, and the tail as *varshā* [TB 3.10.4.1, ŚB 10.4.5.2].

A few words on the meaning of the fire ritual are in order here. In the words of Heesterman (1957):

> To the Vedic thinker the whole universe was constantly moving between the 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 upanishad 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 notion of the Vedic sacrifice is to capture the magic of change, of time in motion. Put differently, the altar ritual was 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 represented the universe. The ritual culminated in his ritual rebirth, which signified the regeneration of his universe. In other words, the ritual was a play dealing with paradoxes of life and death enacted for the *yajamāna*'s family and friends.

To understand the astronomical references in *Śatapatha Brāhmana* it is essential to summarize relevant references in other co-eval or earlier Vedic texts. A good summary of Vedic astronomy is to be found in Shukla (1987).

The *Rigveda* describes the universe to be infinite. It also refers to the five planets as gods and mentions *Brihaspati* (Jupiter) and *Vena* (Venus) by name (*e.g.*, RV 4.50.4 & 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 was called a *nakshatra*. *Nakshatras* are mentioned in the *Rigveda*, and *Taittirīya Samhitā* (TS 2.3.5.1-3) specifically mentions that they 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 *nakshatras*. In later literature the list of *nakshatras* was increased to 28. Constellations other than the *nakshatras* were also known. RV 1.24.10; 10.14.11; 10.63.10 mention the *Rikshas* (the Bears), the two divine Dogs (Canis Major and Canis Minor), and the Boat (Argo Navis). The constellation *Tishya* is invoked in RV 10.64.8; since TS 2.2.10.1-2 says *Tishya* is *Rudra*, perhaps it is Sirius which is meant. *Aitreya Brāhmana* (AB 3.33) speaks of *Mriga* (Orion) and

Mrigavyādha (Sirius). TS 3.4.7 calls the moon *sūrya raśmi*, *i.e.*, one that shines by sunlight.

The lunar synodic month was measured from full moon to the next-in-succession full moon, or from new moon to the next-in-succession new moon (TS 7.5.61.); twelve lunar months constituted a lunar year. In analogy with a civil day, a lunar day was reckoned by dividing the lunar year into 360 parts which were called *tithis* (AB 32.10). The lunar month consisted of 30 lunations (BU 1.5.14). To preserve correspondence between lunar and solar years, intercalary months were inserted at regular intervals (see, *e.g.*, RV 1.25.8).

We will present the astronomical basis of the *agnicayana* ritual which will help us understand several aspects of Vedic astronomy. These insights will also help us understand the astronomical framework that lies at the organization of the *Rigveda*.

II. The *Brāhmana* Texts

The *Brāhmanas* describe the Vedic ritual and elaborate many stories briefly noted in the *Rigveda*. These texts can be placed in a chronological sequence based on linguistic and astronomical considerations. In the *Kaushītaki Brāhmana* (KB 19.3) is mentioned that the winter solstice took place at the new moon of the month of *Māgha*. On the other hand, the winter solstice was marked by the beginning of *Māgha* in the later *Vedānga Jyotisha*. Sengupta (1938b) argues that if the KB 19.3 statement were based on a precise determination of the solstice day, then it refers to mid-fourth millennium B.C.E. Since we have no knowledge that such a precision existed, an error of 10 days will bring us into the 3rd millennium B.C.E. The astronomical references in the *Śatapatha Brāhmana* have been interpreted by Sengupta to c. 2100 B.C.E. These dates do not establish that the editions of the texts that have come down to us have not been reworked subsequently. Yet an inner chronology that has the same relative order as one based on linguistic considerations is a matter of significance.

The political references indicate that *Kaushītaki* is the oldest text since it speaks of early Vedic kings, such as Daivodāsi Pratardana (KB 26.5). On the other hand, in the *Aitreya*, one speaks of the consecration of Bharata Dauhshanti (AB 8.23) by the famed sage Dīrghatamas Māmateya, but Janamejaya Pārikshita (AB 8.21) is also mentioned. This latter reference places the *Aitreya* after the Mahābhārata battle. On the other hand, Śatapatha mythologizes the drying up of the Sarasvatī river in the story of Videgha Māthava and his priest Gotama Rāhūgana (ŚB 1.4.1.10-15). This would place this text in an age somewhat after the actual drying up of the Sarasvatī around 1900 B.C.E. The hydrological evidence also indicates that before this epoch Sarasvatī had changed its course, so it is also plausible that the myth in *Śatapatha Brāhmana* refers to the earlier episode.

A clear reference to a Sarasvatī that is lost in the desert occurs in *Pañcavimśa Brāhmana* (PB 25.10).

III. Bricks and Enclosing Stones

Bricks to be used in altar construction were classified into two types: ordinary (*lokamprinā*) and special (*yajushmatī*). Each *yajushmatī* brick was consecrated in a specific manner and each such brick was marked in a unique way. Bricks were built in different shapes to different measurements.

ŚB 10.4.3.14-20 describes the total number of *yajushmatī* bricks to be 395. 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 refer to 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 *nakshatra* 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, are once again the integer nearest one third the number of days in the lunar year.

The total lumber of *lokamprinā* bricks is 10,800 which equals the number of *muhūrtas* in a year (1 day = 30 *muhūrtas*). Of these 21 go into the *gārhapatya*, 78 into the eight *dhishnya* hearths, and the rest go into the *āhavantya* altar.

The fire altars are surrounded by 360 enclosing stones (*pariśrita*), of these 21 are around the *gārhapatya*, 78 around the *dhishnya*, and 261 around the *āhavantya* (ŚB 10.4.3.13). The *āhavantya* includes the *dhishnya*, therefore the number of days assigned exclusively to the *āhavantya* is 261-78= 183 days, which is equal to the days in the *uttarāyana* of a 366 day year. The choice of the 21 days for the *gārhapatya* is from the unique symbolism of this number. It is from 12 months, 5 seasons, 3 worlds, and the sun (TS 7.3.10.5, ŚB 7.1.1.34) or, as *trishaptā*, it may refer to 'three sevens' as in *Rishis* (planets), and the like (RV 10.90.15; AV 1.1.1). It may also refer to five *mahābhūtas* (earth, water, fire, air, space) plus five breaths (*prāna, apāna, vyāna, udāna, samāna*) plus five *jñānendriyas* (organs of cognition) plus five *karmendriyas* (organs of action) plus the *antahkarana* (the inner ear). Another basis for the choice of 21 is sketched in Section 11. Once the numbers 21 and 183 are chosen, the number 78 becomes the only choice for the *dhishnya*. The *dhishnya* hearths are in one layer in a size of 18 *angulas* in either a square or circular form. The number of enclosing stones equals the number of bricks used in a

dhishnya hearth, and these are eight each for five of them with the remaining three using 6, 11, and 21.

The bricks and the enclosing stones also represent the metres (ŚB 10.1.2, 10.3.2.1-13) but we will not explore that issue here.

4. Equivalence Through Area

Seidenberg (1983) shows how the *Śulbasūtras* clearly indicate that the *gārhapatya*, the *āhavanīya*, and the dakshināgni are all to have the area of one square *purusha*. *Purusha* 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 metres), then as areal measure it is about 4 square metres. 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 and it is represented by a square. The *dakshināgni* is a semi-circular figure.

The *mahāvedi* altars were generally made in five layers of bricks reaching to 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 *Rigveda* knew of such an altar because *purusha* 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 *purusha*. The body of the basic falcon-shaped altar was 2 × 2 (= 4) square *purushas*, the wings and the tail were one square *purusha* each (Figure 2).

To make the shape look more like that of a bird, the wings were lengthened by one-fifth of a *purusha* and the tail was lengthened by one-tenth of a *purusha* (Figure 3). This defined the total area of 7 1/2 square *purushas* at the end of the first construction. On the second construction the area of the altar was increased by one square *purusha* to a total of 8 1/2 square *purushas*. Further constructions successively increased the area by one square *purusha* 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

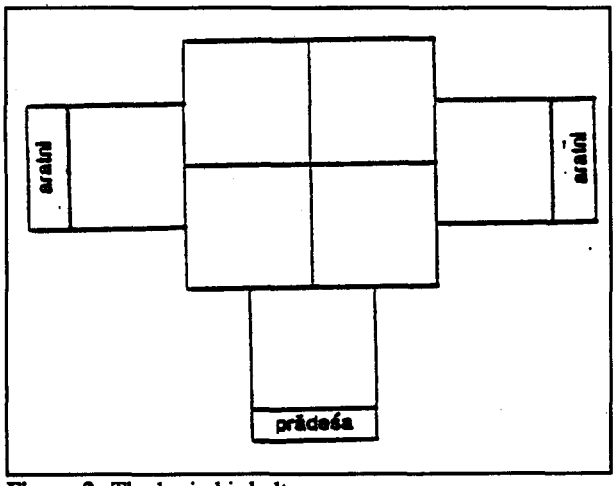

Figure 2. The basic bird altar.

geometric problems including that of the theorem of the diagonal. It is important to note that the total number of altars to be built in a sequence is 95.

V. Equivalence Through Number

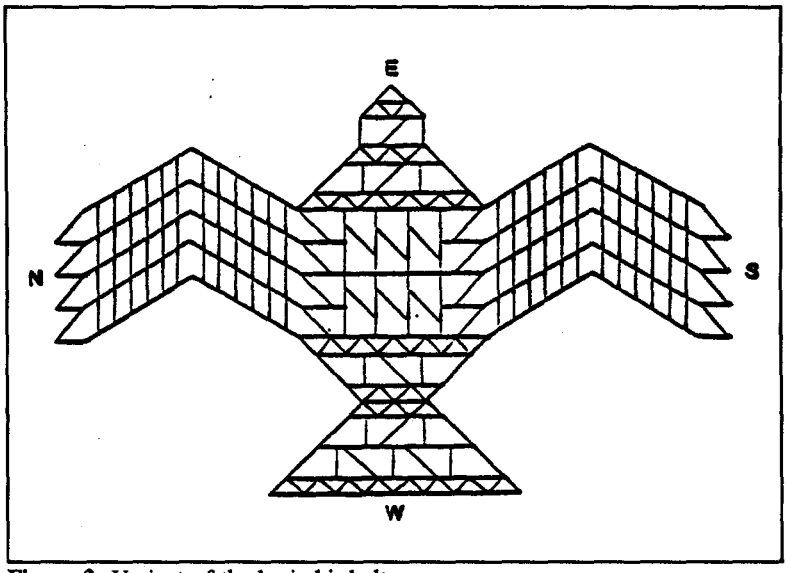

Figure 3. Variant of the basic bird altar.

The first step in abstraction requires a representation of a phenomenon through a number. If two phenome-na 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 must have preceded the philosophy of equivalence through area.

Consider *Aitreya Āranyaka*. 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, metre, 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]

It is not surprising then that the *Caraka Samhitā* counts the total number of *asthi* (bones, teeth, nails, hard cartilages) in the human body to be 360 (Rāy and Gupta 1980). It appears that this count was obtained by considering the 308 bones of the new-born (before they fuse into the smaller count of 206 in the adult), 32 teeth, and 20 nails. The underlying hypothesis in the physiology of *Caraka* is that somehow each *asthi* should be associated with each day of the year. Clearly the number 360 was considered fundamental

owing to the central place assigned to the periodicity of the year in Vedic philosophy. All this constitutes a reasonable first hypothesis in the construction of a scientific theory.

V.a. An abstract property of numbers

Equivalence was not held by number alone. Some of the argumentation is related to abstract relations of numbers. Thus ŚB 10.4.2.1-18 indicates that 720 (the nights and days of a year) has exactly 15 factors (1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 16, 18, 20, 24) which are smaller than the companion. This is pointed out as a parallel to 15 days of waxing and 15 days of waning of the moon.

VI. *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 *Ashtamūrti*. *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 *Daksha*. These refer to the change in the reckoning of time brought about by a precession of the earth (Tilak 1893, Kramrisch 1981).

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 (Kuiper 1983).

The *Śatapatha Brāhmana* speaks of the Seven *Rishis* 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, to transcend, time.

Prajāpati is a metaphorical representation of time. *Prajāpati* is also the year (ŚB 5.1.1.1). So 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 the *Baudhāyana Śulbasūtra* 7.17 the bricks can be replaced by *mantras* leading thus to the *chandaścit*. The year was thus represented by the Vedic stanza called *brihatī*, 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 such as 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 *Rohinī*, his daughter. This is metaphorically represented by the slaying of *Prajāpati* by *Rudra*. Much earlier a similar passage was represented by the myth of *Vritra* 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 (Santillana and Dechend 1969). The frame of time was represented in *Atharvaveda* as *skambha*, the cosmic pillar (AV 10.7).

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 *purusha* = 120 *aṅgulas* and, therefore, the area of 7 1/2 sq. *purusha* for the basic altar equals 108,000 square *aṅgulas*.

The *Rigveda* had long spoken of *purusha* (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 *purusha* to 101 1/2 square *purusha*. Since tradition ascribes the authorship of the *Śatapatha Brāhmana* to Yājñavalkya (Mahābhārata 12.11739), this may be called the Yājñavalkya cycle. This cycle is obviously the product of 5 × 19.

VII. The Seven *Rishis* and the Saptarshi Era

The tradition of the seven *Rishis*, the stars of the Ursa Major, in India is an ancient one and it goes back to the *Rigveda* (Mitchiner 1982).

> Of those Rishis born together, they say that the seventh is born by himself [*saptatham ekajam*] while six are twins, God-born *Rishis* [*shal idyamā rishayo devajāh*]. (RV 1.164.15; AV 9.9.16, 10.8.5)

While the *Rishis* are not named in the *Rigveda*, there is a mention of *Viśvāmitra* as being God-born (*devajāh*) in RV 3.53.9. References in the *Brāhmanas* and the *Upanishads* suggest that the unpaired star is *Atri* which is ϵ Ursa Major, the fifth in order of listing of the stars of the group.

Purusha Sūkta (RV 10.90) visualizes the cosmic giant *purusha* 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 Rishis as the lips of the cosmic person.

On the other hand, 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, *Vasishtha* 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 *Vasishtha* 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 *Rishis*.

The later texts make a geographical identification of the *Rishis* which parallels their mapping in the sky. And as the Vedic Indians spread from their original region in the Northwest India the geographical representation of the *Rishis* changed. This can be seen in the transition from the Vedic literature to the Epic literature and the *Purānas*. It is in this manner that South India is associated with another *Rishi* called *Agastya* which represents Canopus.

There is a further identification of the *Rishis* with the human head doubtless inspired by the identification of the primal person, *purusha*, in the sky.

VII.a. The Saptarshi Era

ŚB 2.1.2.1-5 speaks of a marriage between the *Rishis* and the *nakshatras*; specifically it is mentioned that the *Rishis* were married to the *Krittikās*. In the *Purānas* this notion of marriage is elaborated when it is clearly stated that the *Rishis* remain for a hundred years in each *nakshatra* (*e.g.*, VP 2.37.413-417). It may be noted that the original core *Purāna* is to be dated to the same epoch as the *Śatapatha Brāhmana*, but it is not clear that the elaboration in the *Purānas* was meant in the statement of ŚB 2.1.2.1-5.

The significant point here is that the Purānic elaboration implies a centennial reckoning system with a cycle of 2700 years. Such a system has been in use in parts of India for a long time that goes back centuries before C.E. and it is called the Saptarshi era (Cunningham 1883). Each cycle of 2700 years was called a *cakra*, or cycle. By current reckoning in Kashmir, which goes back at least to Kalhana, the Saptarshi era began in 3076 B.C.E.

Mitchiner (1982), in his review of Cunningham's analysis has suggests that the Saptarshi era goes back to 6676 B.C.E. He argues that it is the beginning of this era that is quoted by the Greek historians Pliny and Arrian:

> 1. From Father Liber (Bacchus) to Alexander the Great, they reckon the number of their kings to have been 154, and they reckon (the time as) 6451 years and 3 months [Pliny in *Naturalis Historia* 6.59-60];
> 2. From Dionysos to Sandrocottos (Candragupta Maurya) the Indians count 153 kings, and more than 6042 years; and during this time, thrice for liberty * * * this for 300 years, the other for 120 years [Arrian, in *Indica* 9.9].

Mitchiner argues that several conflicting traditions about the Mahābhārata war can be reconciled if it is assumed that a change in reckoning from a system of 28 *nakshatras* to that of 27 *nakshatras* took place sometime after the time of Candragupta. Mitchiner

suggests that the original list of 28 *nakshatras* (AV 19.8.2) was amended in the medieval times to 27. Since the notion of 27 *nakshatras* also goes back very far as in TS 4.4.10.1-3, it is possible that the two traditions on the Mahābhārata war go back much further than suggested by Mitchiner.

It appears that Mitchiner's reconstruction needs to be modified in one crucial point. It is more likely that the original system of *nakshatras* was 27 and that it was modified to 28 later. This modification required the change of the beginning of the Kali Yuga from 2414 B.C.E. to 3102 B.C.E. The reason why this is more likely to have happened is because it has the support of the internal astronomical evidence as described by Sengupta (1938a).

VII.b. The basis of the Saptarshi Era

It is conceivable that the Saptarshi era might have been known during the *Śatapatha Brāhmana* times. Notice that the altar is made in an area 7 1/2 times that of one *purusha*. With 360 years considered one divine year (MP 142.12), 2700 years equal 7 1/2 divine years. It may be that such a theory led to the popularity of the system of 27 *nakshatras*. It is also significant that the epoch of 6676 B.C.E. is exactly 3600 years earlier than the starting point of 3076 B.C.E. for the Saptarshi era as accepted now. Since it is clear that at the time of the Mauryas, the cycles of the Saptarshi era were counted back to 6676 B.C.E., it appears that the new count that goes back to 3076 B.C.E. was started later to make it as close to the start of the Kali era as possible.

VIII. More On Intercalation

For ready reference note the following facts from modern astronomy:

Solar (sidereal) year = 365.25636 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 it's nominal period was taken to be 360 days. TS 7.1.10.1-3 speaks of the five excess days over the *Sāvana* year of 360 days to complete the seasons, where four days are too short and six 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 *nakshatra* 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 *nakshatra* year being equal to 324 days which is 27 times 12 (Macdonell and

Keith 1912, page 411). In a system of 28 *nakshatras*, the *nakshatra* year equals 336 days. That *Śatapatha Brāhmana* knows the *nakshatra* 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 Rigvedic theme. *Rigveda* 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 can 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. In other words, the basic year was taken to be 366 days, which would correspond to 372 *tithis*. However, 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 *ribhus*, 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 *Vedāṅga Jyotisha* each *tithi* is equated to 9 *bhāmśas*.

The period of five solar years was called a *yuga*. These years were named *samvatsara, 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 Jyotisha* evidence suggests were added at intervals of 2 1/2 years. This would lead, however, to an excess of about 4.688 *tithis* in five years, necessitating further corrections in greater periods.

The *Taittirīya Brāhmana* (TB 3.9.22) calls the year the day of the gods. This indicates how increasing larger *yugas* would have been conceived.

IX. The 95 Year *Yājñavalkya* Period

ŚB 6.1.1.1-3 speaks of how the *Rishis* (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) *purusha* 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).

BŚ 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 *purusha* 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 *purusha* and Seidenberg (1983) convincingly shows that this must have referred to the 101 1/2 square *purusha* 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*. In Section 12 we show that 95 years represent a big period even when the year is taken to be a *nakshatra* year of 324 days. If each altar is taken to represent a *yuga*, the cycle would then become 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 times 95, or a "month" of such a cycle.

X. More On Altar Design

PB 25.17.1 speaks of how the world is set in motion after a 1000 year sacrificial rite (*sahasrasamvatsarasattram*) of *Prajāpati*. 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 the *muhūrta* as a basic measure in the consideration of the grand year of 1,000 ordinary years. A *muhūrta* is to a day as 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 *purusha* which equals 14,400 square *aṅgulas*. This requires drawing a circle around a square of side 1 *vyāyāma* (1 *vyāyāma* = 4/5 *purusha*). It is constructed with 21 bricks in each layer (ŚB 7.1.1.34). With 7 1/2 square *purusha* considered equal to 360 days, the area of the *gārhapatya* altar equals 48 days.

It is also noteworthy that the *gārhapatya* design, as seen in Figure 4, implies a value of π equal to 25/8. Also note that this design uses 20 bricks and the cement used to bind these 20 bricks is taken to be the 21st brick (ŚB 7.1.1.33). Note also that the falcon altar symbolizes all the three years: *nakshatra*, lunar, and solar. The increase in the area in each new construction of the falcon altar is 1 square *purusha* which equals 48 days. The purpose of the increase is to make the altar become closer to the actual year. If the *nakshatra* 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 *tithi*s. On the other hand, it may indicate the size of a larger *yuga* by the following correspondence:

1 *tithi* = 9 *bhāmśas* like 1 year (371 *tithis*) = 3339 *bhāmśas*;
48 days expands to a larger period of 48 × 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 *tithi*s is required every year since it is clearly stated that the expanded altar is to be viewed as before as *Prajāpati*. Since we do know that the number of *tithi*s in a year is supposed to be 371.06239, this implies an excess of 0.93761 *tithi*s per year. In 95 years this excess would be almost exactly equal to 89 *tithi*s. It appears that the period of 95 years was chosen because observationally the excess was taken to be 90 *tithi*s or 3 lunar months. Every 95 years a major adjustment of the calendar would then have been required. This also means that the length of the adopted solar year would be 372 - (90/95) = 371.05263 *tithi*s. This 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.

XI. The Rigvedic Astronomical Code

That *Rigveda* was in itself taken to represent a symbolic altar of *mantras* is confirmed by the number of syllables in the *Rigveda*. ŚB 10.4.2.23 describes the *Rik*-verses to be 12,000 *brihatīs*; since each *brihatī* has 36 syllables, this totals 432,000 syllables. Another way to count the syllables is by the 10,800 *pañkti* verses. With 40 syllables to a *pañkti*, it adds up to a total of 432,000 syllables. *Yajurveda* and *Sāmaveda* were supposed to add up to another 432,000 syllables in a proportion of 2:1. Altogether these three *Vedas* add up to 864,000 syllables.

The *Rigveda* consists of 1017 hymns distributed in 10 books. The hymn and the group totals for each book define a set of 20 numbers. Are these numbers accidental or is there a deliberate plan behind the choice? These are the two questions that one may ask.

One would expect that, if the *Rigveda* is considered akin to the five-layered altar described in the *Brāhmanas*, then the first two books should correspond to the space intermediate to the earth and the sky. Now, the number that represents

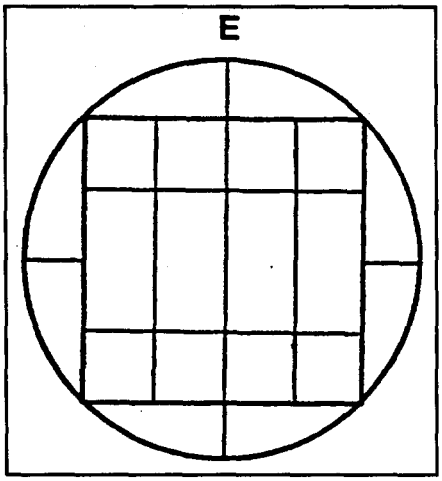

Figure 4. The gārhapatya.

space is 78. When used with the multiplier of 3 for the three worlds, this yields a total of 234 hymns. We find that is indeed the number of hymns in these two books (see Table 1). One may, then, represent the Rigvedic books as a five-layered altar of books, as illustrated by Table 2.

Table 1: Hymns and groups in the Rigvedic books

Books	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

Table 2: The altar of books

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

Note that the structure of this representation has considerable regularity. In particular, Books [4+6+8+9] = 339. Other relationships are apparent from Table 3.

Table 3: Hymns in the altar of books

191	114
104	92
87	75
62	58
43	191

We see also that the number of hymns in the different books satisfy, amongst others, the following relationships (overleaf):

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

(Note further: 1/2 *nakshatra* year + 21 = 1/2 year of 366 days.)

The number of hymns in Books 1 and 10 is 191. This number also satisfies the interesting equality: 191 = 113 + 78, where the significance of 113 and 78 has already been explained.

The fact that astronomical numbers pop up in several hymn totals could not have been a coincidence. Note also the correspondence with the five-layered brick altar; especially how the hymn totals for the first two books are reflect the space number 78.

11.a. The numbers 339 and 108

The question arises whether the total hymn count of 1017 and the group count of 216 have any particular significance. We would also like to understand the significance of the number 339 that we came across before in the discussion on the fire altars. Note further that owing to a pervasive tripartite ideology of the Vedic books, the hymn number should be viewed 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 earths axis, and the southern celestial hemisphere.

Let us consider whether there is any link between the two numbers 1017 and 216. I propose that another parallel with the representation of the layered altar was at work in the group total of 216. Since the Rigvedic altar of hymns was meant to symbolically take one to the sky, the abode of gods, I propose that the number 216 represents twice the basic distance of 108 taken to separate the earth from the sky. The Rigvedic 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. This model is at the basis of the earliest Indian astronomy as well.

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 (the true averages obtained using modern instruments are 107.6 and 110.6 respectively, but 108 should be considered an excellent early approximation). 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. Furthermore, 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, where the mapping of the sky into 27 *nakshatras* 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: $\pi \times 108$ equals, approximately, 339 [This represents an early approximation to π that makes it equal to 3.1389].

Once 108 was arrived at, then 339 could be easily calculated. These estimates may have been refined through mutually related measurements. For example, one could count the number of disks of the sun or the moon that would go into an arc of a specified extent. If the relationship between radius and circumference was not known then one would require very refined observation of the number of sun or moon disks. Since that would vary with the seasons, one can be certain that the value of π as given above was used.

For further circumstantial evidence supporting such 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 *dakshināyana*, 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 Brāhmana* that has been mentioned earlier. In *Atharvaveda* as well the total number of hymns is related to the number 339, being $565 = 339 \times 5/3$.

Also note that the verse total in *Atharvaveda* is 5226 which equals 67×78. Also by one tradition the number of verses in all the four *Vedas* equals 20358 which is 261×78. Clearly, the tradition was aware of the fundamental nature of the number 78 and 261.

11.b. A Rigvedic prime number

Consider now the total number of words in the *Rigveda*. According to Śaunaka, who wrote an early index to the Rigveda, it is 153,826. Since the Rigvedic poetry is in terms of double verses, the half of the word total becomes the more fundamental number. This total is 76,913 which is a prime number.

The question may be asked whether the Rigvedic poets knew of its primality. A categorical answer to this question cannot be provided now.

In any event just as reading a large prime number written millennia ago would be a matter of great historical interest, seeing a prime number in the tradition of word total of the Rigveda is of interest to us. Furthermore, that an index, written millennia ago, concerned itself with the word count, suggests that this count was invested with a special significance.

12. Conclusions

The equivalences by number were at the basis of the altar as the year. This allows us to obtain considerable knowledge about the astronomy of the era of the *Śatapatha Brāhmana*. In particular we find a 95 year cycle as a part of the *agnicayana* ritual. The areas of the fire altars correspond to the broad astronomical facts about the year. However, this exact distribution of the various kinds of bricks needs to be further studied. The fact that the altar increases by one unit area in each new construction indicates the intercalation that is necessary to bring the *nakshatra* year in line with the solar year. This increase goes on until the 95th year when an additional correction would have been made to remove this error. The details of the altar design represent, in code, astronomical facts; we have sketched broad aspects of this code but the details of it are yet to be deciphered. In another paper (Kak and Frawley 1992) it has been argued that the details of the astronomical code imply the use of a linear function to determine the length of daylight with changing seasons in a manner similar to what was used later in *Vedāṅga Jyotisha*.

In other words, we find that the main elements of the astronomy of *Vedāṅga Jyotisha* are already contained in *Satapatha Brāhmana* and earlier books. Specifically, we find clear references to the nominal year of 372 *tithis*, the *nakshatra* 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. The fact that a further correction was required in 95 years indicates that these figures were in themselves considered to be approximate. Assuming intercalation at the end of the 95 year *Yajñavalkya* period we conclude the duration of the year was taken to be 365.24675 days which is quite close to the tropical year. In view of the above facts the dating of c. 1150 to 1370 B.C.E. for R-VJ is not inconsistent with a conservative dating of 2nd millennium B.C.E. for *Satapatha Brāhmana*. Of course *Satapatha Brāhmana* does not speak of any details of motions of planets, but that is not surprising considering that its main purpose is ritual.

The clear conception of the great *yuga* during the age of the *Brāhmanas* as also the notion of the primal person being made out of 7 1/2 *purushas*, when a *purusha* is also equated with 360 years leading to a longer cycle of 2700 years, indicates that the *Saptarshi*

era was known then. This increases the significance of the astronomical evidence from the Vedic literature that has been analyzed by Sengupta and others.

Considering the significance of the number 339 in the hymn count for the *Rigveda*, it is certain that the arrangement of the Vedic books was according to a deliberate astronomical plan.

Abbreviations for Vedic and Puranic Texts

AA	*Aitreya Āranyaka*	PB	*Pañcavimśa Brāhmana*
AB	*Aitreya Brāhmana*	RV	*Rigveda*
AV	*Atharvaveda*	ŚB	*Śatapatha Brāhmana*
BŚ	*Baudhāyana Śulbasūtra*	TB	*Taittirīya Brāhmana*
BU	*Brihadāranyaka Upanishad*	TS	*Taittirīya Samhitā*
KB	*Kaushītaki Brāhmana*	VJ	*Vedānga Jyotisha*
MP	*Matsya Purāna*	VP	*Vāyu Purāna*

REFERENCES

Aitreya Āranyaka (Ed. and transl. A.B. Keith 1909: Oxford)

Aitreya Brāhmana (Ed., with the commentary of Sāyana, S. Sāmaśramī 1894–1906: Calcutta; transl. A.B. Keith 1920: Oxford; reprinted 1981: Delhi)

Atharvaveda (Eds. R. Roth and W.D. Whitney 1924: Berlin; transl. W.D. Whitney 1905: Cambridge; reprinted 1971: Delhi)

Baudhāyana Śulbasūtra (see Sen and Bag 1983)

Billard, R. (1971) *L'astronomie Indienne* (Paris)

Brihadāranyaka Upanishad (see *Upanishads*)

Cunningham, A. (1883) *Book of Indian Eras* (Calcutta; reprinted 1971: Delhi)

Frawley, D. (1991) *Gods, Sages and Kings* (Salt Lake City: Passage Press)

Gonda, J. (1984) *Prajāpati* and the Year (Amsterdam: North-Holland Publ.)

Heesterman, J.C. (1957) *The Ancient Indian Royal Consecration* ('S-Gravenhage: Mouton)

Heesterman, J.C. (1991) "Hinduism and Vedic ritual," *History of Religions*, **30**, 296-305.

Holay, P.V. (1990) *Vedic Astronomy* (Nagpur: *Shri Babasaheb Apte Smarak Samitee*)

Indica of Arrian (Ed. and transl. E.I. Robson 1929: London)

Kak, S.C. (1986) "The roots of science in India," *India International Centre Quarterly* **13**, 181-196.

Kak, S.C. (1987a) "On astronomy in ancient India," *Indian Journal of History of Science* **22**, 205-221.

Kak, S.C. (1987b) "On the chronology of ancient India," *Indian Journal of History of Science* **22**, 222-234.

Kak, S.C. (1992a) "The Indus tradition and the Indo-Aryans," *Mankind Quarterly* **32**, 195-213.

Kak, S.C. (1992b) "Astronomy of the Vedic altars and the *Rigveda*," *Mankind Quarterly* **33**, 43-55.

Kak, S.C. (1993) "Astronomy in the *Śatapatha Brāhmana*," *Indian Journal of History of Science* **28**, 14-33.

Kak, S.C. and Frawley, D. (1992) "Further observations on the Rigvedic code," *Mankind Quarterly* **33**, 163–170.

Kaushītaki Brāhmana (Ed. E.R.S. Sarma 1968: Wiesbaden; transl. A.B. Keith 1920: Cambridge; reprinted 1971: Delhi)

Kenoyer, J.M. (1991) "The Indus valley tradition of Pakistan and Western India," *J. of World Prehistory* **5**, 331-385.

Kramrisch, S. (1981) *The Presence of Śiva* (Princeton: Princeton University Press)

Kuiper, F.B.J. (1983) *Ancient Indian Cosmogony* (Delhi: Vikas Publishing)

Macdonell, A.A. and Keith, A.B. (1912) *Vedic Index of Names and Subjects* (London)

Mahābhārata (Ed. B.S. Sukthankar *et al.* 1933–59: Poona; transl. P.C. Roy 1884–96: Calcutta)

Matsya Purāna (Ed. H.N. Apte 1907: Poona)

Mitchiner, John E. (1982) *Tradition of the Seven Rishis* (Delhi: *Motilal Banarsidass*)

Naturalis Historia of Pliny (Ed. and transl. H. Rackham *et al.* 1939–62: London)

O'Flaherty, W. D. (1985) *Tales of Sex and Violence: Folklore, Sacrifice, and Danger in the Jaiminīya Brāhmana* (Chicago: The University of Chicago Press)

Pañcavimśa Brāhmana (Ed., with a commentary of Sāyana, A. Vedāntavāgīśa 1870–74: Calcutta; transl. W. Caland. 1931: Calcutta; reprinted 1982: Calcutta)

Pargiter, F.E. (1913) *The Purāna Text of the Dynasties of the Kali Age* (London; reprinted 1962: Banaras)

Pargiter, F.E. (1922) *Ancient Indian Historical Tradition* (London; reprinted 1972: Delhi)

Pingree, D. (1973) "The Mesopotamian origin of early Indian mathematical astronomy," *Journal for the History of Astronomy* **4**, 1-12.

Rāy P. and Gupta, H.N. (1980) *Caraka Samhitā: A Scientific Synopsis* (New Delhi: Indian National Science Academy.

Rigveda (Ed., with the commentary of Sāyana, M. Müller 1880–92: London)

Renou, L. and Filliozat, J. (1947) *L'Inde Classique, I* (Paris)

Roy, S.B. (1975) *Ancient India: A Chronological Study* (Delhi)

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

Sastry, T.S. Kuppanna (1985) *Vedānga Jyotisha of Lagadha* (Indian National Science Academy, New Delhi)

Śatapatha Brāhmana (Ed., with the commentary of Sāyana, A. Weber 1903: Calcutta, transl. J. Eggeling 1892–1900: Oxford; reprinted 1969: Delhi)

Seidenberg, A. (1962) "The ritual origin of geometry," *Archive for History of Exact Sciences* **1**, 488-527.

Seidenberg, A. (1978) "The origin of mathematics," *Archive for History of Exact Sciences* **18**, 301-342.

Seidenberg, A. (1983) "The geometry of the Vedic rituals," in *Agni*, Frits Staal (ed.), Vol. **2**, 95-126.

Sen, S.N. and Bag, A.K. (1983) *The Śulbasūtras* (Indian National Science Academy, New Delhi)

Sengupta, P.C. (1938a) "Bhārata-battle traditions," *J. Royal Society Bengal Letters* **4**, 393-413.

Sengupta, P.C. (1938b) "Solstice days in Vedic literature," *J. Royal Society Bengal Letters* **4**, 415-434.

Shukla, K.S. (1987) "Main characteristics and achievements of ancient Indian astronomy in historical perspective," in *History of Oriental Astronomy* (Eds. Swarup, G., Bag, A.K., and Shukla, K.S.; Cambridge: Cambridge University Press)

Smith, B. K. (1989) *Reflections on Resemblance, Ritual, and Religion* (Oxford: Oxford University Press)

Taittirīya Brāhmana (Ed., with the commentary of Sāyana, R.L. Mitra 1859: Calcutta)

Taittirīya Samhitā (Ed., with the commentary of Mādhava, 1860–99: Calcutta; transl. A.B. Keith 1914: Cambridge; reprinted 1967: Delhi)

Tilak, B.G. (1893) *Orion, or Researches into the Antiquity of the Vedas* (Poona; reprinted 1989: Pune)

Upanishads (Ed. Jagadīśa Śāstrī, 1970: Delhi)

van der Waerden, B.L. (1974) *Science Awakening II: The Birth of Astronomy* (New York: Oxford University Press)

Vāyu Purāna (Ed. R.L. Mitra 1880–88: Calcutta; Ed. and transl. Rāmapratāpa Tripāthī 1987: Prayāg)

Vedānga Jyotisha. See Sastry (1985) and Holay (1990).