Time, Space, and Astronomy in Angkor Wat

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Introduction

Angkor Wat's great Hindu temple has been called one of mankind's most impressive and enduring architectural achievements. It was built by the Khmer Emperor Sūryavarman II, who reigned during AD 1113-50. One of the many temples built from AD 879 - 1191, it arose when the Khmer civilization was at the height of its power. Although Viṣṇu is its main deity, the temple, through its sculpture, pays homage to all the Vedic gods and goddesses including Śiva. Figure 1 presents a plan of the temple complex upto the moat and Figure 2 presents a plan of its inner three galleries.

The astronomy and cosmology underlying the design of this temple was extensively researched in the 1970s.[1] An update of this research was recently presented by Eleanor Mannikka.[2] Basically, it was found that the temple served as a practical observatory where the rising sun was aligned on the equinox and solstice days with the western entrance of the temple, and many sighting lines for seasonally observing the risings of the sun and the moon were identified, some of which are shown in Figure 3. Using a survey by Nafilyan[3] and converting the figures to the Cambodian cubit or *hat* (0.43545 m), it was demonstrated that certain measurements of the temple record calendric and cosmological time cycles.

The most impressive aspect of this representation is that it occurs both at the level of the part as well as the whole in a recursive fashion, mirroring the Vedic idea of the microcosm symbolizes the macrocosm at various levels of expressions. This is done not only in the domain of numbers and directions, but also using appropriate mythological themes, and historical incidents. The mythological scenes skillfully use the oppositions and complementarities between the gods, goddesses, asuras, and humans defined over ordinary and sacred time and space.

Speaking just of numbers, the various lengths and circumferences of units representing the motion of the moon may equal 27, 28, 29 (nakṣatras or days of the month), 354 (days of the lunar year), or 360 (tithis of the lunar year). Other lengths represent the solar year (360, 365, or 366) or larger time cycles. For example, the west-east axis represents the periods of the yugas. The width of the moat is 439.78 cubit; the distance from the first step of the western entrance gateway to balustrade wall at the end of causeway is 867.03 cubit; the distance from the first step of the western entrance gateway to the first step of the central tower is 1,296.07 cubit; and the distance from the first step of bridge to the geographic center of the temple is 1,734.41 cubit. These correspond to the periods of 432,000; 864,000; 1,296,000; 1,728,000 years for the Kali, Dvāpara, Tretā, and Kṛta yuga, respectively. It has been suggested that the very slight discrepancy in the equations might be due to human error or erosion or sinking of the structure.

In the central tower, the topmost elevation has external axial dimensions of 189.00 cubit east-west, and 176.37 cubit north-south, with the sum of 365.37. This division of the almost exact length of the solar year into unequal halves remained a mystery for some time until it was found to be connected with the Śatapatha Brāhmaṇa numbers for the asymmetric motion of the sun.[4]

In this article, we review the main aspects of the cosmology and astronomy of the temple. Since the connections of this to the Purāṇic ideas have been well described by Mannikka, our focus is on the connections to the astronomy of the Vedic altars.

The Historical Background of Angkor Wat

The Khmer kings of Kampuchea (Cambodia) trace their ancestry to the legendary Indian Kauṇḍiṇya and to Somā, a Khmer princess, and this lineage came to be called *somavaṃśa*. In the 7th century, another legendary couple, Kambu and Merā, established a different lineage, the *sūryavaṃśa*. At first there were several warring kings. The unification of the state is seen with King Jayavarman II, who in 802, in a ceremony on Mount Kulen, about 30 km northeast of Angkor, declared himself a "universal ruler" (*cakravartin*).

The kings of the Khmer empire ruled over a domain that, at its broadest, reached from what is now southern Vietnam to Yunan, China and from Vietnam westward to the Bay of Bengal. The structures one sees at Angkor today, more than 100 temples in all, are the surviving religious remains of a grand social and administrative metropolis whose other buildings - palaces, public buildings, and houses - were all built of wood and are long since decayed and gone. As in most parts of India where wood was plentiful, only the gods had the right to live in houses of stone or brick; the sovereigns and the common folk lived in pavilions and houses of wood.

Over the half-millenia of Khmer rule, the city of Angkor became a great pilgrimage destination because of the notion of Devarāja, that has been explained by Lokesh Chandra as a coronation icon. Jayavarman II (802-850) was the first to use this royal icon. According to Lokesh Chandra,

> Devarāja means 'King of the Gods' and not 'God-King'. He is Indra and refers to the highly efficacious *aindra* mahābhiṣeka of the Ṛgvedic rājasūya tradition as elaborated in the Aitareya-brāhmaṇa. It was not a simple but a great coronation, a mahābhiṣeka. It was of extraordinary significance that Jayavarman II performed a Ṛgvedic rite, which lent him charismatic authority.[5]

The increasingly larger temples built by the Khmer kings continued to function as the locus of the devotion to the Devarāja, and were at the same time earthly and symbolic representations of mythical Mt. Meru, the cosmological home of the Hindu gods and the axis of the world-system. The symbol of the king's divine authority was the sign (*linga*) of Śiva within the temple's inner sanctuary, which represented both the axes of the physical and the psychological worlds. The worship of Śiva and Viṣṇu separately, and together as Harihara, had been popular for considerable time in southeast

Asia; Jayavarman's chief innovation was to use ancient Vedic mahābhiṣeka to define the symbol of government. To quote Lokesh Chandra further, "The icon used by Jayavarman II for his aindra mahābhiṣeka, his Devarāja = Indra (icon), became the symbol of the Cambodian state, as the sacred and secular sovereignty denoted by Prajāpatīśvara/Brahmā, as the continuity of the vital flow of the universal (*jagat*) into the stability of the terrestrial kingdom (*rāja = rājya*). As the founder of the new Kambuja state, he contributed a national palladium under its Cambodian appellation *kamrateṅ jagat ta rāja/rājya*. Whenver the capital was transferred by his successors, it was taken to the new nagara, for it had to be constantly in the capital."[6]

Angkor Wat is the supreme masterpiece of Khmer art. The descriptions of the temple fall far short of communicating the great size, the perfect proportions, and the astoundingly beautiful sculpture that everywhere presents itself to the viewer. Its architecture is majestic and its representation of form and movement from Indian mythology has astonishing grace and power. The inner galleries of the temple have depiction of the battle of Kurukṣetra, procession of King Sūryavarman and his ministers, scenes from heavens and hells, churning of the sea of milk, the battle of Viṣṇu and the asuras, victory of Kṛṣṇa over Bāṇa, battle of the devas and asuras, Rāvaṇa shaking Kailāsa with Śiva and Pārvatī atop, and the battle of Laṅkā between Rāma and Rāvaṇa. These and other scences are drawn with great artistic beauty. No wonder, the temple ranks amongst the greatest creations of human imagination.

As an aside, it should be mentioned that some European scholars tended to date Angkor Wat as being after the 14th century. The principal reason was that some decorative motifs at Angkor Wat show a striking resemblance to certain motifs of the Italian Renaissance. This argument, which is similar to the one used in dating Indian mathematical texts vis-a-vis Greek texts, has been proven to be wrong. In the words of Cœdès,[7] "If there is some connexion between the twelfth-century art of the Khmers, the direct heirs to the previous centuries, and the art of the Renaissance, it must have been due to a reverse process, that is to the importation of oriental objects into Europe."

Mannikka proposes[8] that the royal priest Divākarapaṇḍita was the chief architect of the temple. He is the priest most praised in inscriptions; an image of him is to be found at Wat Phu. Divākara is estimated to have lived around 1050-1135.

Astronomy of Altars and Temples

To understand the astronomical aspects of Angkor Wat it is necessary to begin with the Indian traditions of altar and temple design on which it is based. And since the Angkor Wat ritual hearkened to the Vedic past, it stands to reason that its astronomy was also connected to the Vedic astronomical tradition.

Vedic altars

In a series of publications I have shown that the Vedic altars had an astronomical basis[9] 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.

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. 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. Two kinds of day counts: the solar day, and tithi, whose mean value is the lunar year divided into 360 parts. Considering the altar by layers, 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.

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.

Three different years were considered: (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. he 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.

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, 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 is $261 \times 78 = 20,358$.

The Brāhmaṇas and the Śulbasūtras tell us about the altar of chandas and meters, so we would expect that the total Ṛgvedic 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. The number

339 is simply the number of disks of the sun or the moon to measure the path across the sky: $\pi \times 108 \approx 339$. The number 216 represents the distance to the sky, which was twice the distance of 108 to the sun. The *Ṛgvedic* code then expresses a fundamental connection between the numbers 339 and 108.

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

Temples

The temple is considered in the image of the Cosmic Puruṣa, on whose body is displayed all creation in its materiality and movement. Paradoxically, the space of the Puruṣa is (Ṛgveda 10.90), in the sanctuary only ten fingers wide, although he pervades the earth.

The temple construction begins with the Vāstupuruṣa maṇḍala, which is a yantra, mostly divided into 64 (8×8) or 81 (9×9) squares, which are the seats of 45 divinities. Brahmā is at the centre, around him 12 squares represent the Ādityas, and in the outer circle are 28 squares that represent the nakṣatras (Figure 4). The Vāstumaṇḍala with its border is the place where the motions of the sun and the moon and the planets are reconciled. It is the Vāstu in which the decrepit, old Cyavana of the Ṛgveda 1.116.10 asks his sons to put him down so that he would become young again. Cyavana is the moon and Sukanyā, whom he desires, is the sun.[10]

In the basic Vedic scheme the circle represents the earth and the square represents the heavens or the deity. But the altar or the temple, as a represen-

tation of the dynamism of the universe, requires a breaking of the symmetry of the square. As seen clearly in the agnicayana and other altar constructions, this is done in a variety of ways. Although the main altar might be square or its derivative, the overall sacred area is taken to be a departure from this shape. In particular, the temples to the goddess are drawn on a rectangular plan. In Śiva or Viṣṇu temples, which are square, change is represented by a play of diagonal lines. These diagonals are essentially kinetic and are therefore representative of movement and stress. They embody the time-factor in a composition.[11]

In the *Śilpa Prakāśa* 1.90-106, a 9th-12th century Orissan temple architecture text, Rāmacandra Kaulācāra describes[12] the Yoginī Yantra for the layout of the goddess temple. Alice Boner writes,[13] "[the Devī temples] represent the creative expanding forces, and therefore could not be logically be represented by a square, which is an eminently static form. While the immanent supreme principle is represented by the number ONE, the first stir of creation initiates duality, which is the number TWO, and is the producer of THREE and FOUR and all subsequent numbers upto the infinite." The dynamism is expressed by a doubling of the square to a rectangle or the ratio 1:2, where the garbhagṛha is now built in the geometrical centre. For a three-dimensional structure, the basic symmetry-breaking ratio is 1:2:4, which can be continued further to another doubling.[14]

The constructions of the Harappan period (2600-1900 BC) appear to be according to the same principles. The dynamic ratio of 1:2:4 is the most commonly encountered size of rooms of houses, in the overall plan of houses and the construction of large public buildings. This ratio is also reflected in the overall plan of the large walled sector at Mohenjo-Daro called the citadel mound. It is even the most commonly encountered brick size.[15]

There is evidence of temple structures in the Harappan period in addition to iconography that recalls the goddess. Structures dating to 2000 BC, built in the design of yantras, have been unearthed in northern Afghanistan.[16] There is ample evidence for a continuity in the religious and artistic tradition of India from the Harappan times, if not earlier. These ideas and the astronomical basis continued in the architecture of the temples of the classical age. Kramrisch has argued that the number 25,920, the number of years in the precessional period of the earth, is also reflected in the plan of the temple.[17]

As a representation of the macrocosm, change in the temple is described

in terms of the motions of the heavenly bodies. According to Alice Boner[18]:

> [T]he temple must, in its space-directions, be established in relation to the motion of the heavenly bodies. But in asmuch as it incorporates in a single synthesis the unequal courses of the sun, the moon and the planets, it also symbolizes all recurrent time sequences: the day, the month, the year and the wider cycles marked by the recurrence of a complete cycle of eclipses, when the sun and the moon are readjusted in their original positions, a new cycle of creation begins.

The Hindu temple, as a conception of the astronomical frame of the universe, serves the same purpose as the Vedic altar, which reconciled the motions of the sun and the moon. The progressive complexity of the classical temple was inevitable given an attempt to bring in the cycles of the planets and other ideas of the yugas into the scheme.

Numbers at Angkor Wat

The temple has 1300-m north-south axis and 1500-m west-east axis. The temple faces toward the west because that situates it to the east with respect to the worshiper, the appropriate direction for Viṣṇu who is a solar deity. At the heart of the temple are three rising, concentric galleries. Bordering these is further space, and a rectangular moat. About 40 m in from the moat is a laterite wall, 4.5 m high, with large single entrances from the east, north, and south, and five entrances on the west.

Mannikka has suggested that the Vāstupuruṣa maṇḍala at Angkor Wat forms a grid of 49, rather than the standard of 64 or 81.

Various numbers from the Vedic astronomy are encountered at Angkor Wat as simple counts, or measurements in cubits, or *phyeam* = 4 cubits. Some of these represent just the basic constants of the system, while others provide specific information related to the orientation of the temple related to the nakṣatras and the positions of the planets. For an example of the latter, consider that the length of the north-south axis, door to door, in the sanctuary is 13.41 cubits, which according to Mannikka represents the fact that the north celestial pole is 13.43 degrees above the northern horizon at

Angkor. This number is also basic to the second gallery, devoted to Brahmā who is "situated" at the north celestial pole.

The order in which the planets rose over the eastern horizon at the end of July 1131 is represented in the bas-relief of the northwest corner pavilion: Saturn (Agni), Jupiter (Indra), Venus (Kubera), Mars (Skanda), and Mercury (Varuṇa).

According to Mannikka[19], the design of the temple can be seen in three architectural units:

1. *Central sanctuary:* Mount Meru, with 45 gods, the north celestial pole, the centre of the maṇḍala, the spring equinox, the axis of the earth, Viṣṇu, Brahmā, and King Sūryavarman

2. *Circumferences:* the ecliptic, the moon and lunar periodicity, the constellations, the planets, the celestial year, the *kṛta yuga*, the grid of the maṇḍala, the history of King Sūryavarman

3. *Axes:* the building blocks of time (60, 108), the yuga cycles, the solar year, the lunar year, historical dates in Sūryavarman's reign, the maṇḍala and its transformation of time, and, finally, the solar year and lunar time cycles from the vantage point of Meount Meru

Some basic numbers that we encounter frequently in the architectural plan are give below. For more examples see the book by Mannikka which, however, does not recognize the special place of the altar numbers 78 and 261. Neither does it know the correct significance of the number 108.

21 The earth number shows up as the number of steps to the libraries.

27/28 This count of nakṣatras is represented at numerous places; the total inner axes of the sanctuary.

32/33 This represents the number of *devas* and it is found as the number of pillars, windows and various lengths.

44/45 The number of divinities of the Vāstupuruṣa maṇḍala are shown in the total number of steps, main entrance and flanking Central Western entrances. As 450 cubits, various axial entrances and circumference of gallery.

54 As half of the distance in sun- or moon-diameters to the sun or the moon, 54 cubits or 54 *phyeam* are encountered several places on the Western bridge and the outer enclosure.

78 The atmosphere number is found in the central cruciform, inner axes as 20.08 *phyeam*, which equals 80.32 cubits. The 20 steps in several of the stairways to the libraries may also represent the same number divided by 4. Further evidence for that comes from the distance of 19.42 *phyeam* = 77.68 cubits each library, west-east outer axis. Since books represent the 'atmosphere' in reaching the 'sky' of knowledge, its use in the context of library is very appropriate.

108 In-and-out circumambulation of four corner towers together; circumambulation of the central Viṣṇu image from three axial entrances; inner axes of all four corner towers without images; full vertical distance above and below central sanctuary.

130.5/261 As half of the sky number 261, we find it in the circumambulation path to north end chamber, each end gateway. The number is 32.74 *phyeam* which equals 130.96 cubits.

354 The length of the lunar year in days, it is the distance between *nāga* balustrade and first step at end of walkway to upper elevation.

360 In *phyeam*, the circumambulation path around the Cruciform Terrace.

366 Solar axes of gallery from walkway on west to bases on each side.

371 This is the solar year in tithis, and it is found in an in-and-out circumambulation of all four courner towers.

Solar and lunar measurements

The solar and lunar numbers that show up in the design of the Angkor Wat temple are the number of nakṣatras, the number of months in the year, the

days in the lunar month, the days of the solar month, and so on.[20] Lunar observations appear to have been made from the causeway.

The division of the year into the two halves of 189 and 176.37 was recently explained by the author as being derived from the Śatapatha Brāhmaṇa. In layer 5 of the altar described in the Śatapatha, a division of the year into the two halves in the proportion 15:14 is given (Figure 5).[21] This proportion corresponds to the numbers 189 and 176.4 which are just the numbers used at Angkor Wat.

Figure 6 explains the physics behind the asymmetry in the sun's orbit. As one can see, the period from the autumnal equinox to the vernal equinox is smaller than the opposite circuit. The interval between successive perihelia, the anomalistic year, is 365.25964 days which is 0.01845 days longer than the tropical year on which our calendar is based. In 1000 calendar years, the date of the perihelion advances about 18 days. Considering Figure 6 again, the perihelion was roughly on December 18 during the time of the construction of Angkor Wat; and it was on October 27 during early 2nd millennium BC, the most likely period of the composition of the Śatapatha Brāhmaṇa. In all these cases the perihelion occurs during the autumn/winter period, and so by Kepler's 2nd law we know that the speed of the sun in its orbit around the earth is greater during the months autumn and winter than in spring and summer.

During the time of the Śatapatha Brāhmaṇa, the apogee was about midway through the spring season, which was then somewhat more than 94 days. The extra brick in the spring quadrant (Figure 5) may symbolically reflect the discovery that this quarter had more days in it, a discovery made at a time when a satisfactory formula had not yet been developed for the progress of the sun on the ecliptic.

It is possible that the period from the spring equinox to the fall equinox was taken to be about 189 days by doubling the period of the spring season; 176 days became the period of the reverse circuit.

Why not assume that there was no more to these numbers than a division into the proportions 15:14 derived from some numerological considerations? First, we have the evidence from the Śatapatha Brāhmaṇa that expressly informs us that the count of days from the winter to the summer solstice was different, and shorter, than the count in the reverse order. Second, the altar design is explicitly about the sun's circuit around the earth and so the proportion of 15:14 must be converted into the appropriate count with respect

to the length of the year. Furthermore, the many astronomical alignments of the Angkor Wat impress on us the fairly elaborate system of naked-eye observations that were the basis of the temple astronomy.

But since precisely the same numbers were used in Angkor Wat as were mentioned much earlier in the Śatapatha Brāhmaṇa, one would presume that these numbers were used as a part of ancient sacred lore. Looking at Figure 6, we see the count between the solstices has been changing much faster than the count between the equinoxes because the perigee has been, in the past two thousand years somewhere between the autumn and the winter months. Because of its relative constancy, the count between the equinoxes became one of the primary 'constants' of Vedic/Purāṇic astronomy.

The equinoctial half-years are currently about 186 and 179, respectively; and were not much different when Angkor Wat temple was constructed. Given that the length of the year was known to considerable precision there is no reason to assume that these counts were not known. But it appears that a 'normative' division according to the ancient proportion was used.

As it was known that the solar year was about 365.25 days, the old proportion of 15:14 would give the distribution 188.92 and 176.33, and that is very much the Angkor Wat numbers of 189 and 176.37 within human error. In other words, the choice of these 'constants' may have been determined by the use of the ancient proportion of 15:14.

Concluding Remarks

Although it has long been known that the Angkor Wat temple astronomy is derived from Purāṇic and Siddhāntic ideas, the Vedic roots of this astronomy have only recently been identified. We have found the Vedic altar astronomy numbers 21, 78, and 261 in the temple design. The division of the solar year into two unequal halves is explained by the design of the Śatapatha Brāhmaṇa altar on the asymmetric circuit of the sun. We need a more thorough examination of the altar numbers in the design to interpret their significance in the context of different architectural units so brilliantly decoded by Mannikka. For example, was there any obvious influence of the Agnicayana ritual on the phased construction of the Angkor Wat temple?

The decoding of the astronomy of Angkor Wat has opened the way for a similar examination of medieval and ancient Indian temple complexes, which

were also built with basic astronomical observations in minds.

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16. See Kak, *The Astronomical Code ..*, pages 44-46.

17. Kramrisch, S., *op cit,* page 51. Note that this figure is not the best modern estimate of the period of precession.

18. Boner, A., "Introduction" In Kaulācāra, R., *Śilpa Prakāśa*, Boner, A. and Rath Śarmā, S. (eds.). E.J. Brill, Leiden, 1966, pp. xxxiii.

19. Mannikka, *op cit*, page 259.

20. Mannikka, *op cit*, page 274-283.

21. Kak, S., "The sun's orbit in the Brāhmaṇas," *cited above.* This altar is described in detail.

Figure Captions

Figure 1 The plan of the temple complex

Figure 2 The plan of the inner three galleries

Figure 3 Astronomical alignments for the observation of the sun and the moon

Figure 4 The Vāstupuruṣamaṇḍala of 81 squares

Figure 5 The Śatapatha altar describing the circuit of the sun

Figure 6 The asymmetric circuit of the sun