SRI YANTRA

Rediscovering the Geometry of Construction and its Mensuration

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[Ritual specification of the composition of nine intersecting triangles central to the diagram *Sri Yantra* requires that the triangles be laid out such as to make twenty-four triple intersections. The deceptively simple geometry demands impossibly huge number of mathematical iterations when logic of modern mathematics is applied to ‘solve it’. Geometrically accurate traditional drawing of *Sri Yantra* is not available. Instructions noted in ancient commentaries are also only approximate and do not give accurate results - the instructions appear even cryptic and coded. In recent times, renewed interest in the diagram as an object of meditation has led to fresh research on it seeking ‘similar looking alternative constructs’ based on comparative analysis of sacred geometry of the east and the west. Yet accurate construction of *Sri Yantra* has remained elusive*.*

This paper presents a reconstruction of the traditional instructions on drawing the Sri Yantra based on analysis of background classical treatises and offers the highest level of accuracy so far achieved. The current article examines Sri Yantra as an instrument of unified astronomical and astrological measure of universe and shows that it is a mathematical diagram of geocentric space and time as understood in Hindu thoughts. The geometry of the diagram incorporates an annual correction equivalent to 5.25875 days at the time of winter solstice (*daxinayan*) and reconciles the circle representing the universe spatially measured as having an angle of 3600 and time wise as ‘one year’ of 365.25875 days or as many degrees. The magic of the diagram is this accurate statement of time and space through the geometry of triangles.]

*Sri Yantra* is the most exalted *Tantric* diagram and represents Goddess Sri or *Tripurasundari,* the Goddess of Universe. As the house of *Sri,* the diagram is also the universe herself; for this reason the term ‘*saranakona*’ was used in *Saundaryalahari,* an eighth century composition on *Sri Yantra*. Asthe primordial *Shakti, Sri* is mirror of consciousness for the radiant Siva and so *Sri Yantra* also provides refuge to the Self of Siva says *Kamakalavilasa*, a *Tantra* devoted to *Sri Yantra* (Rawson, 1978). Just as the onlooker sees itself in the reflected image on a mirror and without a mirror the object-onlooker would have remained unaware of itself, *Sri Yantra* reflects a similar tripartite actualization of Siva as a conscious Self is awakened through the *Shakti*. Thus, in the center of *Sri Yantra* is a composition of nine interpenetrating triangles; four *Siva* triangles (with apices up) and five *Shakti* triangles (with apices down). According to *Saundaryalahari* (Venkatanathacharya, 1969)the house results when the triangles-composition is bounded by four outer circuits - eight-petal lotus, sixteen-petal lotus, three rings and three lines[[1]](#endnote-1):

 *rt'le{Z>Ls07}M lzjo'jltleM k~rle®lk*

 *k|leÌfleM zDef]g{jle/lk d"nk|s[ltleM .*

 *rt'ZrTjfl/+zå;'bnsnf>lqjno—*

 *lq/]vfleM ;fw+{ tj z/0fsf]0ffM kl/0ftfM ..*

(*- Saundaryalahari.xi -* from Laxmidhara’s commentary)

*Sri Yantra* displays all three cosmic activities of creation, preservation and dissolution together. The triangles represent this triadic nature and the name *Tripurasundari* also literally tells of the pattern of three-ness in nature and Her essence.

**Figure 1: *Sri Yantra***

Several triads are invoked in *Sri Yantra* like in Her verbal form, *Pancha-dasaksari Mantra* (fifteen-lettered-sounds), which is recited as three groups of letter-sounds and purports the recognition of the three processes of phenomenal existence *srshti-sthiti-samhara* (creation, preservation and dissolution) the three dimensions of existence conveyed by *agni-surya-soma* (Fire, Sun and Moon) and *iccha-jnana-kriya* (volition, cognition and action), the three qualities of evolution *sattva-rajas-tamas* (pure, radiant, dark), the three body states *jagrat-svapna-sushupti* (wakefulness, dream and deep sleep), the three aspects of knowing *jnatr-jnana-jneya* (the knower, the knowledge and the known), the three dimensions of self *atma-antaratma-paramatma* (the individual self, the inner self and the supreme self). Of these triads, philosophical elaboration of *agni-surya-soma* (Constellations/Fire, Sun and Moon) also has potential to define the universe in concrete terms. All triads are, however, worshipped as one and undistinguished into components.

That the Yantra of *Tripurasundari* is in the form of the universe is reiterated in *Bhairavayamala Tantra* (cf. ‘*rs|+ lqk'/;'Gbof{ a|≈df08fsf/dL˘jl/*’). Since traditionally *Sri Yantra* has been modeled as three-dimensional hemispherical solid with spherical triangles, it would be logical to speculate that the diagrammatic form is a two-dimensional projection of the universe. Bhasker-raya (*Bhavanopanisat*, ca. 1730 AD) states that Sri-chakra evidences itself in the forms of time, world and heavens (e.g. “sfn¿kf] b]Zf¿k peo¿k”) and in the renewal of ‘*tithi*’ and within it resides the essence of Sri-chakra, not outside (e.g. “O{b[Zf:o r lgTo+ kl/jt{dfg:o sfn¿kltlyrœfm:ofGt/]j >Lrœfm+ lti7lt, g alxM .”). (Rao, 1983)

**Figure 2: Hindu Image of the World ‘*jambudvipa*’ and the Heavens**

Bhasker-raya’s revelation that ‘Sri Yantra simultaneously images time, world and heavens’ explains the three-fold understanding of the term ‘*brahmanda*’ in Hindu thoughts. An accurate Sri Yantra, as it diagrammatically mirrored the pattern of renewal of *tithi*,time according to moon, also seems to have became a dial of luni-solar universal time early on and found utility as a instrument in *ganitajyotish*, the computational branch of astrology. As there is limited abstraction in Hindu definition of time (*panchanga*), the mathematical specification of *Sri Chakra* could be rationally revisited through this set of governing rules (cf. root ‘*yam*’ in ‘*yantra*’). These rules, while governing and guiding the process of invocation of its godly power and meditation, may also give us a method and measure of geometric construction of the diagram, *Sri Chakra*[[2]](#endnote-2).

*Sri Yantra* derives its geometrical significance through the particular arrangement of triangles that result in twenty-four triple intersection points (with one side each of three different triangles). From the point of view of geometric construction, it is the specification of these triple-intersections or *marmasthana* that provide a test of accuracy of any diagram and truth of the method of construction. These intersection points get special attention in worship for they are said to show the presence of harmony (*samarasya*) in the union of Siva and Shakti. The faithful worship 28 such points (*asmin chakre astabimsati marmasthanani* …) including the four enclosures of *Siva* on the outside. The ritual practice of taking the outer four *Siva* circuits as *marmasthana* appears esoteric at first glance, but in reality they cloak a construction geometry that can accurately reveal the 24 triple intersection points within. (See how the squares and circles of *Siva* circuit three and four enable drawing of critical angles needed to construct the triangles accurately)

Accurate geometric model of *Sri Yantra* have not been handed down by the ancients and only drawings, paintings and etchings of *Sri Yantra* used as religious artifacts for invocation of spiritual power and meditation have survived. As miniatures of a complex diagram, they look visually correct enough to serve their religious purpose but the limited sharpness of lines used does not give them a high level of geometric accuracy. Instructions for drawing of *Sri Chakra* outlined in traditional texts also do not result in any better accuracy as the measures given are rounded off to integer values. The following discussion of Sri Yantra and some of its uses tell how precise the drawing needs to be.

***Sri Yantra* and Hindu Measure of Time in Space**

It is most likely that observation of the phenomena of renewal of time and seasons in nature had provided the philosophism for the processes of phenomenal existence, i.e. the *trayam* of ‘creation, preservation and dissolution’ in the first place. Primary dimension of time stated in the geometry of *Sri Yantra* is the circular angle that synthesizes and totals its tripartite components of Moon, Sun and Fire. This can be discerned from the edict of *Rudrayamala* that ‘*trikhandam matrikachakram somasuryanalatmakam*’. It has been said in classical texts that *Marichi,* the aboriginal speck of light, has a body of 360 rays and so also are the number of days in a standard year implying that a circular angle measures 3600 (*amsa*). According to *Vairabayamala,* the rays of Fire, Sun and Moon are respectively 108, 116 and 136 in number and the total is evidently the original speck of light. Here, Fire is *Naxyatra,* the constellations that number 27 and each with four phases make up 108:

 *Astottarasatam vanheh shodashottarakam raveh*

 *Sattrimshduttarasatam chandrasya cha vinirnayah*

It is even more notable that Kaivalyashramaconcludes his step-by-step description of the method of drawing Sri-yantra given in *Saubhagyavardhani* thus:

“[Thus] the best shri cakra is formed,
with its center having the form of trembling fire,
with eight and twelve and fourteen lights of fire. || 8 ||
… … …
the cakra is divine, completely splendorous,
consisting of the nature of moon, sun and fire. || 9-10 ||

Clearly, it is universe as ‘time’ that is meant by the nature of moon, sun and fire and it is what Sri-chakra consists of - the set of nine interpenetrating inner triangles.

Hindu time was presented and measured as the periodicity of the nature of play between Sun, Moon and ‘*Naxyatra’*, the constellations, the body of stars representing fire as it appeared to an observer on earth. Subdivisions in the measure of solar time were made by dividing the circle of its apparent path into twelve *rasi* (house of the zodiac) of thirty degrees each. Each *amsa* makes a standard *savan* day and 30 days make the standard *savan* month. The span of solar year (*saur* versa) on earth was computed at 365.25875 *savan* days[[3]](#endnote-3) and the apparent period spent by the sun in its passage through a house was taken as a solar month (*saur mas*). The principle of division of a year into twelve months was replicated in ‘times’ according to moon and constellations also. With its phases the moon provided convenient measure of a lunar month - the period from one new moon to the next. Twelve such months made the lunar year and it totaled 354+ *savan* days. The houses of 27 constellations were equally spaced angularly from its neighboring ones and made up the full circle with 108 rays in total. The span of time taken for the passage of moon in the circle of its apparent path through a total of nine rays in a sequence of space of three consecutive constellations made up *Naxyatra* month.

The triadic nature of time was reinforced in *Naxyatra* time as it embodied the essence of ‘three movements’, the movement of moon around the earth, the movement of earth around its axis and the movement of earth around sun, thus the number 27, which is 3x3x3. The time according to moon, divided into *tithi* days, was further triangulated through the formulation of two other characteristics, ‘*karan*’ and ‘*yoga*’ and made time into *panchanga -* a five-faceted entity. The definition of lunar time through the triad of ‘*tithi, karan* and *yoga*’ specifies a very fine accuracy in measuring celestial time.

The tilt of the axis of rotation of earth with the plane of its revolution around sun made time according to sun complicated making lengths of days and nights vary with their own rhythm and the sun appeared to annually trace a path like that of figure eight as it toured between the northern (with point of *daxinayana* where the annual southward movement begins and the days start becoming longer in the northern hemisphere or winter solstice) and southern (with the *uttarayana* point) skies around the equator. The recognition of this aspect of time (*ayana*) is made in the specification and construction of *Sriyantra* as *damaru*, which is formed when individual sets of Siva and Shakti triangles intersect and form a similar figure. The time dimension of this figure seems to have led Hindu philosophers to propose *damaru* as the drum of Siva as the lord-master of *pralaya*,the dissolution.The elliptical path of revolution itself brought about a seasonal variation and a different rhythm of renewal within the year according to sun. This dimension of time (*ritu*) was stated, among others, by the ratio 15:14, as the Hindu mathematician sought to approximate the ratio of the periods between the winter solstice and summer solstice and the other way around (respectively about 189 and 176 days or a ratio of 107.38). The differences in the annual cycle of renewal as well as extent of ‘real’ years of time according to Sun (the year with 365+ days) and Moon (the year with 354+ days) was reconciled further with the idea of ‘*yuga*’ of five years duration, thereby identifying another point of renewal. The cyclical period of *yuga* of 5 *saura versa* was equal to 61 *savan* months, also 62 *chandra* months and 67 *naxyatra* months; in angular terms, a whole number of *savan* months also means that it was a quantity that could be constructed (since total angle is 1830 degrees or 5x3600+300) using basic geometry of a circle.

General properties of circle simply enable construction of a hexagon and angle of a house of Sun sign or *rasi* of 30 degrees or *amsa* can be constructed by halving. But the house of a constellation or *Naxyatra* equals an angle of 13.33 *amsa* (degrees) or 800 *kala* (minutes), which cannot be constructed as simply and calls for a knowledge of trisection of angles. When even mathematics of today does not have a general method of trisecting an angle by compass and straight edge construction, for Hindu astrology to make assumptions that require such computations commonly is daring unless some simple method[[4]](#endnote-4) of trisecting angles was already known. More probably, methods of approximate trisection of some key angles were established and then coded as a formula for particular application, say, for exact drawing of a phase of a Naxyatra, which was to be 200 *kala.* Ancient Hindu mathematicians had established that the ratio of circumference of a circle to its diameter was a constant (π) but irrational number and this made mathematics based on the measurement of arc only approximate. The approximation required assuming a small portion of the circular segment of the circumference as straight, the accuracy of measures increasing as the smaller arc segments are considered. That a very high level of accuracy was sought after is clear from *Ganitapad* written by Aryabhatt I in 499 AD (e.g. “For a circle of diameter 20000, the circumference is approximately 62832”) or the statement of Shakalya, a scholar of *Vedic* times (“1/96th part of a circumference looks straight”). It can be observed that Shakalya’s prescription gives an accuracy level stated in terms of smallest angle 225 *kala* – an angle that can be constructed by halving and quartering. *Ganitajyotish*, however, still needed ways to draw exactly a phase of a Naxyatra (or an angle equal to 200 *kala*). Sri Yantra seems to mark the time of institution of a new level of tolerance in celestial computations set by taking arc of 100’ angle as ‘straight’ (1/216th part of circumference) replacing the Vedic standard.

**Figure 3: Method of drawing regular triangle, square and pentagon from a circle**

If it was possible to somehow draw the angle 800 *kala,* then subsequent halving and quartering will enable one to draw the total 108 phases or rays assigned for *Naxyatra*.Simple extrapolations would then be sufficient to draw 116 and 136 rays assigned for sun and moon. Also Hindu mathematics of time extensively uses 1/9, 1/12, 1/30 and 1/3 divisions of 300 (called *navamsa,* *dwadasamsa, trimsamsa* and *drescana* of a *rasi*). Of course, 1/9th division (*navamsa*) of *rasi* also conveniently measures the Naxyatra and its phases (30/9 = 90/27 = 360/108).

Also as Hindu astronomy used angle 240 to account for the tilt of the axis of earth in assessing the elevation of sun, the ability to draw the angle by subdivision of a circular angle was called for. The 240 angle could be drawn through construction of an equiangular pentagon and ancient geometry shows examples of some very close methods for drawing regular pentagon. (Fig. 3 above shows one such method.)

The new moon was the key reference point of time in the cycle of days, months and years on earth; on this day the moon was said to enter the sun and the union of Sun and Moon on the new moon day was the cause of creation (*ritu*) itself. A renewal of time of celestial order was said to occur at eclipse. The lesser cycles of days, months, years and *yuga* (5-solar years) run their course within the great year *adhisambatsara,* a period of 25920 solar-years and said to be made up of 33 eclipses. The great importance of eclipse in the concept of time and universe led to the conceptualization of the points of intersection between orbit of Moon around Sun and orbit of Earth around Sun, the spatial and temporal junctures required for occurrence of any or all eclipses, as heavenly bodies (of unseen and evil influences) *Rahu* and *Ketu* and were given place among the nine ‘*graha*’ (with Sun, Moon, Mars, Mercury, Jupiter, Venus and Saturn) making the universe. It was actually the periodicity of certain eclipses that was used by the Hindu mathematician to establish the span of *adhisambatsara* (92x82x5 or 3602/5 or 3600 x60x60x60/300) the great year. By intent or coincidence, this span also measured the precession of the direction of tilt of Earth’s axis. A higher order of renewal of celestial time or ‘a gain of a full year of another kind’ had been measured. This celestial period was also divided into ‘six celestial seasons’, each spanning 4320 years and one thousand such seasons (cf. *sahasradalapadma*) made a *mahayuga* 4320000 years! Also one thousand *mahayuga* made a *kalpa*, a day of Brahma - possibly an allusion to the period of 100 ‘seasons of the sun’ equal to one-sixth of time taken by the Sun to complete its own revolution around its galactic center (which has been estimated by modern astronomy at around 250 million years), also taken as the common multiple of the periodicities of the remaining eight of the *navagraha*, the nine heavenly bodiesof Hindu Sky.

Modern astronomy has established that ‘axial tilt of Earth varies between 21.50 and 24.50 with a periodicity of 41000 years and direction of tilt gradually undergoes precession, moving in a slow circle over a period of about 25,800 years’ causing a precession of equinoxes and change of position of Earth in its orbit at which seasons occur. ‘*Ayana*’ in *Ganitjyotish* computes the same durations at 43200 and 25920 years respectively and actual measurements of time was based on observations of eclipses, which was affected by changing axial tilt as that also caused changes in tilt of orbital plane of Moon (on average 5009’) vis-a-vis the ecliptic.

*Sri Yantra* as a ‘Universal Dial of Time’ would have shown the measure and mechanism of renewal of time in all its cycles of *versa, yuga, mahayuga* and *kalpa*. The dial could have been used as a graphic tool for prediction of eclipses. The ratio of distance from Earth to the diameter of both Sun and Moon was taken at 108 for prediction of eclipses - and this magical ratio would indeed give almost unfailing prediction as the diameter of the shadow of Earth at the position of Moon is 1023’ whereas apparent mean diameters of Sun and Moon are respectively 32’2” and 31’37” (or ratios of 107.32 and 108.73 as per measures presently established).

**Sri Yantra and the human body**

Tantrik treatises draw very many parallels between the human body and the universe; even their origins are attributed to similar situations e.g. ‘*avam pindandamutpannam tadvad-brahmandamudvabhau*’. It has also been said that both the animal body and the universe show the union of Siva and Shakti forces (‘*sivashaktyatmakam viddhi jagadetach-characharam*’). The implication that Sri Chakra is one’s own body is often made and makes the correspondence a matter of mental structuring. The goddess Tripurasundari is deification of ‘pure consciousness, energy and unconditioned will’ that are at the heart of being human.

It is in the location and nature of ‘power’ centers in the human body and its psycho-physical characteristics that the parallel is drawn with *Sri Chakra -* the human body has a similar disposition of bodily circuits as the circuits of the diagram. Like the total of the rays of the triad of fire, sun and moon, the rays attributed to six key bodily *chakra* also add up to 360 to symbolically make the body of rays at *Sahasra chakra*, the circuit of 1000 petals. The detailed distribution of rays among the bodily *chakra* and their association with the contributing sources is stated in the 14th stanza of *Saundaryalahari*. The importance given to this detail is notable and may hint at some mathematical logic of *Sri Chakra* itself. The rays assigned are 56 at Muladhara and 52 at Manipura (the pair totaling 108 equal to fire), 62 at Svadhisthana and 54 at Anahata (the pair totaling 116 of the sun) and 72 at Visuddha and 64 at Agnya (which total 136 of the moon).

Parallel between the human body and *Sri chakra* is also drawn through the perceived ordering of breath. The sum total of all the breaths is said to be the mother-goddess herself (cf. *devi lalita sarvatmana svasasamastirupena*). The texts name the period of time we take to breath 360 times as ‘*nadika’* and sixty *nadika* make a day with a total of 21600 breaths[[5]](#endnote-5) - this system exhibits interesting parallel in measure of angle in spherical space. It would be interesting to note that ancient spherical geometry texts enjoin us to draw the circle with diameter 3438 units so that the circumference was of length 21600 units. In the pattern of distribution of breaths, the *nadi-chakra* and its correspondence with *Sri-chakra* one may find further hints of mathematical processes involved:

600 at Muladhara taking 5/3 *nadika [The bhupura]*

6000 at Manipura taking 50/3 *nadika [The asta-dala-padma]*

6000 at Svadhisthana taking 50/3 *nadika [The shodasa-dala-padma]*

6000 at Anahata taking 50/3 *nadika [the chatur-dasara]*

1000 at Visuddha taking 25/9 *nadika [the bahir-dasara]*

1000 at Agnya taking 25/9 *nadika [the antar-dasara]*

1000 at Sahasra taking 25/9 *nadika [The bindu]*

It is interesting to note that all are divisible by 200, the angular measure equal to one phase of Naxyatra. The resulting dividends using 200 as divisor on the number of breaths assigned to *nadi-chakra* are 3, 30, 30, 30, 5, 5 and 5; in the *rasi-chakra*, as a parallel, these numbers translate into a series which is obtained by consecutive trisection of an angle of 4500 (135 phases) into 1500, 500, 16.660 i.e. (27+3), (30, 30), (15, 15), (5, 5), 5 of the phases of Naxyatra (cf. 5400+600, 6000, 6000, 3000, 3000, 1000, 1000, 1000 minutes each). We will see later that the accurate drawing of angle 16.660 (i.e. 5 phases or 1000’ or 500/3) is critical in the construction of the *Sri-yantra*. Likewise, the angle for which 1000’ is a *trikhanda* (1/3) i.e. 3000’ or 500 is also needed in the construction.

**Sri Yantra and the symbolism of numbers**

The symbolism of number ‘3’ is obvious in the triads of *Tripurasundari*. This is further restated by imposition of symbolism of number nine in the overall diagram - the diagram has nine triangles and nine enclosures. In number terms, this effectively breaks the quantity 32 as sum of numbers 4 and 5 and reveals the right triangle of sides 3-4-5, the ‘Pythagorian’ set:

5 + 4 = 9 OR (5 + 4)(1) = 9 OR (5 + 4)(5 - 4) = 9 OR 52 \_ 42 = 9 OR 52 \_ 42 = 32 , thus, 32+ 42 = 52 …

The ‘tenth’ *mudra-shakti* or attribute of Goddess *Tripurasundari* is known as *Tri-khandini*, the power of trisection. This symbolizes the role of such mathematical processes as dividing the circular angle into 3, 9 and 27 divisions (i.e. drawing the angles of measures 1200, 400 (which is 900 minus 500)[[6]](#endnote-6) and 800’ in the construction of *Sri* *Yantra*. These trisections when applied to the measuring system of angle in the circle and its division into four quadrants by cardinal direction rays bring about many incommensurate angle measures, which were expressed as round numbers (called *asannamana* in traditional literature of mathematics). A theoretical constructive geometry for trisection of angles is still unknown and is said to be a virtual impossibility- in such a situation, the division of angles into *trikhanda* of a *rasi* and the *charan* of the *Naxyatra,* required to diagram Hindu ‘time’ and used in Sri-yantra, may give us insights into cases of trisections of angles 500 and 400.

**Drawing the *Sri Yantra***

The commentary on *Saundaryalahari* by Laxmidhara mentions two different methods of drawing, the inside-out method and the outside-in method – possibly a constructional response to the two different cults of invocation, the path of *shristi-krama[[7]](#endnote-7)* or creation- evolution and the path of *samhara-krama[[8]](#endnote-8)* or dissolution.

**Laxmidhara’s *Shristi-krama* method following the order of creation:**

Prescribed to adherents of *Daxinachara* or ‘Right Hand Path’ cult, it approaches the construction inside out. Triangle Δabc with apex pointing down is first drawn (Fig. 5) and then the position of the centre (*bindu*) is fixed. This is followed by drawing Δdef, also with apex down, and with its base located a little over the centre point. The circuit of *astara*, the eight cornered diagram in the centre is completed by drawing Δghi with its base drawn through the apex of Δabc and its own apex pointing up.

The instructions give no measure or proportion and require a lot of trials and errors before one is able to make even a close approximation. Since the method uses expansion of diagram outwards using the triple intersections as basis and so has perfect reproduction of *marma* - a less than perfect guess of proportions will have the vertices of the outermost triangles failing to fall on the circumference of the enclosing circle.

It can be seen from the diagram that accurate setting up of the three innermost triangles is determined by the accuracy of the two outer triangles and specification of the innermost set of three triangles also establishes the four outer triangles. All the remaining five triangles can be simply drawn because of the triple intersection conditions. Thus, if a construction of Sri Yantra is possible outside-in, then, by the same logic it would be possible to draw an as accurate a diagram inside-out also. Therefore, Fonseca’s inference (1984, pp. 39) that Laxmidhara’s method, starting from the centre, is not viable and ‘is simply a red-herring, or a deliberate attempt to mislead’ cannot be right.

 Fig. 4: The Inside-out Method

The other method mentioned in Laxmidhara’s commentary approaches construction outside in: it instructs to start by drawing the nine chords or lines (e.g. ‘j[Qd¢]gj®]vflnlvTjf’ etc. ) forming the base of each triangle but again gives no clue as to how the required chords may be fixed. A later commentator, Kaivalyasrama, has provided more detailed instructions and measures on this approach and most of the recent analyses of proportion, measure and geometry of construction of *Sri Yantra* have been based on these instruction as transliterated in *Saundaryalahari* (ed. Sastri and Ayyangar, 1977).

**Kaivalyasrama’s *Samhara-krama* method following the order of dissolution:**

This method detailed in the commentary of Kaivalyasrama and prescribed to adherents of *Samayachara* or ‘Left Hand Path’ cult approaches construction in an outside-in manner. The construction begins with the reference circle and proceeds in towards the centre completing the Shakti circuits of triangles last. The second stage of construction starts again from reference circle and proceeds outwards to draw Siva circuits.

Fig. 5: The Five Shakti Chakra (*Left*) and The Four Siva Chakra (*Right*)

To draw the five Shakti circuits, the following are the instructions of Kaivalyasrama[[9]](#endnote-9):

1. Draw a reference circle of required diameter and its vertical diameter.

2. Divide the diameter into 48 equal parts and draw nine chords, perpendicular to the vertical diameter and such that they pass through 6th, 12th, 17th, 20th, 23rd, 27th, 30th, 36th and 42nd segments from the top.

3. Draw the base of triangles by rubbing off a given measure of length from the ends of each chord e.g. rub off from each end of the first, second, fourth, fifth, sixth, eighth and ninth chords 3, 5, 16, 18, 16, 4 and 3 units respectively. The third and the seventh chords form the base of the two largest triangles.

4. Draw the five triangles with apices pointing down by joining (i) ends of the third chord to bottom end of the vertical diameter, (ii) ends of the second line to centre of the ninth line, (iii) ends of the fourth line to centre of the eighth line, (iv) ends of the fifth line to centre of seventh chord and (v) end of the first line to centre of the sixth line. Similarly join (vi) ends of the seventh chord to the top end of the vertical diameter, (vii) ends of the eighth line to centre of the first line, (viii) ends of the sixth line to centre of the second line and (ix) ends of the ninth line to centre of the third chord and construct the four triangles with apices pointing up.

To draw the Siva circuits, following instructions are given:

1. Divide the circumference of the reference circle into eight segments starting from the ends of the vertical diameter and identify the cardinal and corner points. With each point as centre, draw a semicircle of radius three units and enclose the eight-petals lotus by a circle. (Measure for the circle not given.)

2. Divide the outer circle into sixteen segments and draw the sixteen-petal lotus. The measure for the petal is not given but Sastri and Ayyangar’s drawing shows a similar spacing. Enclose this sixteen-petal lotus in a circle and add two circles around it at equal spacing. (Again measures for circles are not given).

3. Construct three squares on the outside with equal spacing from each other and the innermost square not to touch the outermost circle (but no sizes are given.) Mark off four doorways on the four sides, each equidistant from either extremity. Rub off the inner spaces.

Although the instructions are more than sufficient for drawing the five *Shakti Chakra*, plotting of triangles with the given bases and apices shows errors at all points purported to be triple intersections. It was seen from the discussions on *Shristi-krama* method that triple intersection specifications and a sequential plotting enables full plotting of the diagram if the location of 1st, 3rd, 6th, 7th and 9th chords are known. Also information on location of 6th chord can be replaced by the rub-off measure for 1st chord. A plotting of the diagram taking just these data from Kaivalyasrama will still show that the error get cumulated in the pair of triple intersections in 6th chord. Error free diagrams can be constructed by adjusting value for any one data (and keeping the other four fixed) at a time[[10]](#endnote-10). Evidently, all measurements given are rounded integer values of actual dimensions and *not even a single data* is exact. For this reason alone, the so-called ‘alternative methods’ proposed by some researchers (Fonseca, 1984; Bolton and Macleod, 1977), who have sought to remove such errors through adjustment of values of the base angles of ΔABC and ΔFDE, could not be totally error free.

It is clear that the rounding up of data into integer values (for a circle of radius 24) is behind the errors. For greater accuracy, chords and rises available for a circle of radius 3438 units (with circumference of 21600 units or *kala*) could be used; it can be shown to a significant level of accuracy (225/32 or 7.03125 minutes) that the arc of angles (*chap*) smaller than 225 minutes (*kala*), which appears straight, is also same in length (7.03124) to its perpendicular (*jya*) up to the fourth place of decimal! Kaivalyasrama’s own reference for positioning the seventh chord would have been 4328 (*brihajjya* for the radius of circle 3438 units) thus giving him a 144 times greater accuracy[[11]](#endnote-11) (cf. 30.2129 in place of 30 for the circle with radius of 24 units). However, *brihajjya* of other chords are not available from traditional sources.

It is clear that the two large triangles that have vertices in the circumference of the circle are non-congruent - this can be inferred from the rounded measures of 17 and 30 units given for 3rd and 7th chords (congruence will require set of measures such as 17 and 31 or 18 and 30). The extent of non-congruence measures the residual power of the diagram, which is the energy of creation in this case. The five triangles of creative nature, called *sivayuvati*, through their varying sizes and as they get penetrated by the four *siva* triangles, reveal and represent *shakti*, the energyof the diagram. Both the published studies of constructive geometry of *Sri Yantra* in recent history[[12]](#endnote-12) have assumed congruency of these triangles, which is contrary to the philosophy and meaning enshrined in the idea of *Sri Yantra* itself and its triangles and has led to diagrams that could not be right even as they may look close to it. Use of congruent triangles, made by Fonseca for reasons of construction (Fonseca R. , 1986) and by Bolton and Macleod for aesthetic reasons (Fonseca R. , 1986), for construction of *Sri Yantra* known for its energy and power denudes it’s very basic philosophical character and requirement!

Fonseca has proposed a method of ‘reproducing the *Sri-chakra*’based on the use of √5 diagonals of a quartered square and suggests interpreting it both as a microcosm and a mnemonic device. However the diagram he has created has all the triangles except the ninth are symmetrical about the horizontal axis (N-S axis of the microcosm) whereas Kaivalyasrama’s original specifications require all triangles to be asymmetrical. Stripped of its asymmetry, Fonseca’s diagram ceases being a *Sri-chakra* and becomes at best a mnemonic device for the geometry itself. Similar but limited congruency has also been assumed by Bolton and Macleod from ‘aesthetic’ consideration leading to the same loss of meaning.

Figure 6: The Non-congruence of Triangles

In the correct *Sri Yantra*, the two largest triangles are, thus, incongruent and also circumscribed by the reference circle (*maryadabritta*) i.e. the chords of the circle are their bases. As these two triangles more determinate than others, analysis of the geometry of *Sri yantra* has focused on these triangles (ΔABC and ΔFDE in figure) and their base angles. With the rises of 17 and 30 given for a circle with radius 24, respectively for ΔABC and ΔFDE, the resulting base angles are 53.33240 (B/C) and 52.23870 (D/E). Simple approximation trials will show that measure of their base angle should lie between 510 and 540 if all the nine triangles are to be contained within the reference circle. As values of these angles are very close to some well known angles[[13]](#endnote-13) in Western mathematical aesthetics, most western studies appear to have been misguided into establishing the measure of these key angles by comparison with such ideas as Pythagorian triangle, Kepler’s triangle, Golden Rectangle, Pyramid, etc. Since the objectives of Sri Yantra and these geometric forms are so widely different, the results have missed the idea behind Sriyantra.

Bolton and Macleod (1977) proposed a common angle of measure 51050’ equal to the base dihedral angle of the Great Pyramid of Cheops. Fonseca (1986) proposes another common measure of 53007’48.37” (the larger of the base acute angle of a 3-4-5 right-triangle) as it can also be constructed using compass and straight edge only. If we take hint from ancient geodesy that the *kranti* of the sun and the rise of the angle of 150 are same (footnote 11), the base angle of ΔFDE would be 52030’ (= 45+7030’). Incidentally, this angle also can be drawn using compass and straight edge (by fixing the chord through a straight line drawn at an angle of –150 at the center of the circle). The other angle is different from this and slightly larger as is visually evident from Sri Yantra drawings from ancient documents. This latter angle must also have meaning within Hindu classical construct of the universe. We will explore possible measurements for both the angles from the perspective of time and seasonality according to Hindu philosophy.

It becomes clear from the foregoing discussions that the universe was understood as a space-time-continuum populated by heavenly objects (such as the Sun, the Moon, Earth, planets and stars) perennially moving, each with its own particular rule of periodicity. The movements and periodicities in Nature manifested itself as passage and renewal of time (quantified as days and nights, months, seasons, years and eons etc.) in the life of the living and provided the triadic philosophism of ‘creation, preservation and dissolution,’ the three processes of the universal phenomena. Bolton and Macleod (1977) paraphrase that ‘*Sri-yantra* is a 'cosmogram' - a graphic representation of the universal processes of emanation and re-absorption reduced to their essential outline’. Although this is almost literal inference of the Sanskrit process terms in the triad *pralaya-laya-vilaya,* it leaves out the process of preservation i.e. *laya* or *sthiti* altogether and misses the central theme of triadic continuum. Fonseca (1985) concludes that cosmological significance ascribed to the diagram did not determine the form but that it masked a constructive utilitarian geometry of subdividing the square and circle- such a stance is a contradiction in terms as utility of an icon (of cosmos) or its geometry must be at least the representation of the object or phenomenon! Observation of parallels between its form and works on spherical geometry of ancient mathematicians such as Barahamihira suggests that the cosmogram could have been used in graphic determination of time and space (in *ganitajyotish*).

**Tiwari’s Method for Drawing *Sri Yantra*:**

Instructions available for drawing Sri Chakra from classical sources are incomplete and approximate only and, therefore, mathematically accurate measures and proportions will need to be established from consideration of its objectives and philosophies. Study of relevant traditional mathematical literature on space and time, the twin representational characteristic of universe, shows that chords and perpendiculars (*kojya* and *jya*) were used to simplify angular computations in spherical trigonometry as a circle is essentially a mesh of chords and perpendiculars.

As these computations were extensive and time consuming, charts with different levels of accuracy and showing difference of perpendiculars (*jya-antar*) at 150 interval were made available by expert mathematicians for astrologers so they could exactly map the space with angular location of the celestial objects at any particular time. For example a 665 AD treatise called *Khandakhadyaka* of Brahmagupta gives data for a circle of radius 150 as 150 angle is one half of a *rasi* or *griha* (*grihardha* *chapanam*). Thus, when Bhasker (*Siddhantasiromani 1150 AD*) was giving the perpendicular (*jya*) 1397 in the circle of radius 3438, it was meant to be a specification of angle 240 (*asvankavisveatra jinam shajiba*).

Given this, specification of angular measures as perpendiculars and chords line segments with the level of accuracy determined by the assumption that the arc of 225 minutes angle looks straight. My trials show that Sriyantra seeks to represent space and time to the level of accuracy that took 100 minutes segments as straight and showed that the ‘error’ in time measure that results from this level of accuracy is to the tune of 5.25875 days for the 360 days year. This was magical because they had calculated that the actual length of solar year was indeed 365.25875. It must have been for such reasons that the basic triangles in Sriyantra is constructed using radial lines at angles 100 minutes apart and well related to the Solar mansions of the *rasi* and the Lunar mansions of the *naxyatra*:

150 or 900 minutes (1/2 of *rasi*), 500/3 or 1000 minutes (5/9 of *rasi* and 5/4 of *naxyatra*)

Just as the angle of 240 is a representation of the earth’s axial tilt with the plane of the ecliptic, so the angular difference between the plane of the orbit of the moon and the ecliptic (measured in modern days as 5009’) and the points of intersection of orbital planes in space, called *Rahu* and *Ketu*, critical in producing eclipses during new or full moon was represented through angles 500 and 400, which gave the angle 50 on either side of 450, the corner direction line.

Since there can be no doubt that angular specifications are more true as angles themselves, if the angles so specified could be drawn, then there should be no error in the diagram at all as this will nullify any error that could creep in with the change into parameters that can only be approximate. Therefore, the method proposed here specifies angles to draw the various chords required for the nine triangles and the accuracy of the diagram is directly linked to the accuracy of drawing of the specified angles only. The method of drawing Sri Yantra proposed is based on interpretation of some of the available instructions with angles of importance to *ganitajyotish* and some aspects of properties attributed to the diagram and object of which it is an icon of according to the *Tantrik* philosophical literature on *Sri Yantra*.

It has been already noted that the *Tantrik* practitioner also counts the four outer Siva enclosures as *marma* or triple intersection. Since the specification of 24 triple-intersections offer a test of accuracy of the diagram and truth of the method of construction, the ritual worship of the four outer chakra in a manner equivalent to the triple-intersections makes it suspect that these four circuits contain information that can assure the accuracy of the construction of the inner circuits. Trials actually confirm that exacting construction of the basic geometry of the four outer *Siva Chakra* can help draw the triangles exactly with just the compass and straight edge. In the *Siva Chakra* seems to lie hidden the instructions for the construction of *Shakti Chakra*. Ironically, in the instructions transliterated by Shastri and Ayyanger, those for the *Siva Chakra* portion of the diagram are not only incomplete but also without measurements and does not offer any way of checking on its accuracy. Other ancient commentaries offer concrete measurements.

Dabral cites the instructions as coming from the adepts and provides an elaboration of the *Samhara krama* the outside in method, particularly the construction of the outer circuits (Debral, 1991):

“Draw a vertical line (Brahmasutra) and divide it into 72 parts. On both the east and west ends (top and bottom respectively) leave a margin of 1unit each and again 12 ½ units and draw a circle in the centre such that its radius is 22 ½ and the diameter line add up to 45 units. On the outside of this circle and on either side, draw the eight-petal lotus and its karnika within 4 ½ unit divisions, sixteen-petal lotus and its karnika within 5 unit divisions and in the remaining four units on either side make a circle and square (bhupura).…divide the diameter into 48 parts… etc.”

It is notable that diameter (OA in Figure 7) of the reference circle is specified as 45 in relation to the overall square of side 72. If we construct a 3-4-5 right triangle ΔOEG (with EG equal to 36 units and OF 27 units), the middle point C on the hypotenuse OE provides the reference circle with radius 22 ½ units. The square that circumscribes this circle will have a diagonal equal to 22.5(2√2) or 63.64 units and a circle circumscribing this square will have a radius OG equal to (22.5√2) or 31.82, which appears to be the exact measure of the round number 32 (22.5+4.5+5=32) specified as radius for the 16-petal lotus circuit. It is likely that Shastri and Ayyenger garbled the instructions for the circuit of 8-petal lotus by mixing its measure of 45 units with its division into 48 parts and reduced the width of the circuit to 3 units, whereas Debral gives the correct measure of 4.5 units.

Figure 7: The Basic Construction for Outer Circuits

In Figure 7, a further circle with O as its center and circumference through the intersection (shown as point Xx) of the perpendicular on F and horizontal through H, the extremity of the diameter of the reference circle has been drawn, and the radius of this circle OI will measure 4.5√61 or about 35.15, which is very close to radius 35 specified as bounding circle. Whereas the angle BOX (point X is on circle with radius OI at the intersection of the vertical line through A) measures 50.190; a circle of radius 35 will similarly yield an angle of 49.990. It is obvious that there is a circle in between the two circles that can be used to exactly draw angles 500. Further, it can be observed that arc drawn with center H and through point Xx, gives the point Cx on the reference circle and angle CxOB approximates 1/3 of 500. From such trials, it becomes clear that the three squares and the three circles specified between 35 and 36 divisions and that make the Siva Chakra three and four (*brittatraya* and *chaturasratraya*) potentially enabled the adept to draw angles 500, 400 (which were 1/3rds of angles 1500 and 1200) and their 1/3s (16.660 and 13.330) quite accurately. In a way a compass and straight edge method of trisecting the angles is hidden in these two circuits. It must be for such reasons that the *tantrik* takes them as *marma* also.

16.660 and 13.330 are important angles in the Hindu construct of the universe with its 27 *Naxyatra* evenly dispersed around the center and each constellation covering an angle of 13.330; also, as each Naxyatra was divided into four *charan* of 3.330 each, the difference of these angles provided standard measurements. Also as astrological computations had *navamsa* (1/9th) of a *rasi* (each zodiacal sign extending to cover 300) as an important measure and the extent of the 5th 1/9th division was of paramount considerations (just as 150 angle identified the middle of the *rasi*), 16.660 was used in its own right. In Sri Yantra, the ends of the chords of the two main triangles respectively subtended 16.660 and 150 at the center and the correct base angles for them would be respectively 53020’ and 52030’. Through such angles, the upper half of the diagram signified night (moon and *naxyatra* interplay) and the lower half signified day (sun and *rasi* interplay). The ability to draw the angles 16.660 and 13.330 accurately also allowed the computations to get to greater accuracy than was possible with the 225’ angles drawn through halving and quartering process. In a sense the sum of the series ¼+1/16+1/64…had been geometrically reached through trisection of the angles, 4500, 1500, 500, etc.

Therefore, the following measures (angles and lengths are stated correct to fourth decimal place) and processes are proposed:

1. Draw the *brahmasutra* and divide it into 72 parts by halving and trisecting as required. Draw a 3-4-5 right triangle with its vertex at the center point, perpendicular as 36 and base 27. Draw the reference circle of diameter 45 through half-way point on the hypotenuse. Similarly draw the circle with diameter 54 units. Locate the point intersection of the horizontal through the top extremity of the diameter of the circle with radius 22.5 units (H) and the perpendicular on F of the circle of radius 27 units and draw a circle through it and with its center at O. The radius would measure 35.1461.

Figure 8: Drawing 500 angle at the Center

2. Trisect the line segment 36 of one unit length and draw three squares (*chaturasra traya*) of sides 36, 35.6667 and 35.3333 units as Siva Chakra 4.

3. Draw the circle of radius 35 units. Trisect the space between the two circles of radii 35 and 35.1461 and make two additional circles with the centers at O and the radii through the new trisected points. These will have radii of 35.0974 and 35.0487.

4. Locate the intersection (X) of circle of radius 35 with the perpendicular on F. Join it to the center of the circle to construct an angle of 500 (49.99480) at the center.

5. Draw a circle through the intersection of circle of radius 35.0487 and the horizontal through H and with its center at H. This will intersect the reference circle at Cx and an angle of 16.66370 will be formed at the center.

6. Rub off the circle of radius 35.1461. Retain the three circles (*brittatraya*) of radii 35, 35.0487, and 35.0974 as Siva Chakra 3.

It should be noted that where Dabral mentions only one circle and one square as the third and fourth *Siva* circuits, Kaivalyasrama states that these circuits are ‘a ring of three circles drawn close together (*brittatraya*) bounded by three squares on the outside (*chaturasratraya*), equally spaced and just clear of the inner circle’. The above dimensions reflect the high refinement required to draw the two outer circuits within the 36th division of the reference diameter.

Figure 9: Drawing 16.660 angle at the Center

7. Between the circles of radius 22.5 and 27 draw eight petals of a lotus symmetrically on cardinal and corner axes. This will be *astadalapadma* Siva Chakra 2.

8. Between circles of radius 27 and (22.5√2) or 31.8198 draw sixteen petals of a lotus symmetrically on cardinal, corner and intermediate axes. This will be *sodasadalapadma* Siva Chakra 1.

That the very fine proportions and measure specified for drawing the circles and squares making the two outermost *Siva-chakra* provide for a straight edge and compass method of drawing the angles 16.660 and 500 actually provides a method of trisecting 500 (as shown in Fig. 9 and 10 above) required to measure time according to *naxyatra.* It will be seen from the following steps of drawing that these angles are also needed to be drawn to properly draw *Sri Yantra.* We can also see that the diameters of the two circles making the two inner *Siva* circuits (that carry the eight and sixteen petal lotus patterns as symbolic seat for the *Shakti-chakra*)display a relationship similar to the measures of Sarsen Circle and Aubrey Circle of Stonehenge. This indicates how such proportions and angles are crucial in accurate reading of solar and lunar time or the relative movement of Sun and Moon. It may also be noted here that the rays of the rising sun also make a 500 angle on June 22 underscoring the importance of this angularity in relating movement of Sun and earth. (for Stonehenge see, Fonseca 1995)[[14]](#endnote-14).

**Figure 10: Drawing the first set of Triangles**

Drawing of these four *Siva* circuits thus give us lines which subtend angles 500 and 1/3rd of 500 (= 16.660) at the centre. The method of drawing the 1/3rd of 500 can be used to draw angles measuring 13.330 and 136.660 also. Whereas all these angles will be used to represent the universe in the night sky mode (the upper part of the *Shakti-chakra* portion of the diagram) with appropriate details of Naxyatra positions, the lower part of the diagram will represent the same in the day sky mode with the appropriate details of position of Sun. In angular sense, if Naxyatra are related through 500 and its 1/3rd, Sun is related through 450 and its 1/3rd. Thus a mathematical ‘*ahoratra*’ dial is indicated through asymmetry and non-congruence of triangles thus incorporated. The angles 450 and 500 (which also measures 400) also enable construction of the angular difference between the plane of the orbit of the moon and the ecliptic (measured in modern days as 5009’) critical in predicting eclipses!

The following steps of construction of the inner Shakti circuits specify angles, and not chords, to draw triangles and uses sequence of construction taking triple intersection property into account.

1. Draw radial lines at angles -150 and 500/3 and let them intersect the reference circle at E and C respectively. Draw horizontals through these points and make the triangles ABC (Δ1, Sani) and DEF (Δ2, Mangal) with apices at the opposite end of the vertical diameter of the reference circle.

**Figure 11: Drawing the Next Two Triangles using 400 and 500 angles.**

2. Draw a radial line at an angle of 450 and locate its point of intersection on base DE of triangle DEF. Draw a line through this point and the centre (I) of the base BC of triangle ABC. Let this intersect BA at G. Draw another line through the point and the intersection of lines BC and DF and let this intersect AF at H.

3. Draw a radial line at an angle of 500 and locate the point of intersection on the circumference Xx. Draw a chord through it and locate the point J on the *brahmasutra,* the vertical axial line.

4. Draw the triangle (Δ3, Surya) with apex at I, side joining I and G and the base through H.

5. Draw the triangle with apex at J, side through J and the outer triple intersection point on DE and base on the horizontal through G (Δ4, Chandra).

The four triangles are thus drawn. Sides of the fifth triangle (Δ5, Rahu) are also defined by lines joining H and outer triple intersection point on BC.

6. Draw radial lines at an angle of –13.330 and 136.660.

7. Mark the intersection of the 136.660 line with the circumference as Yy. Join Yy with the centre point of chord DE. Identify the intersection of this line with the radial ray of angle –13.330 and draw a horizontal through this point. This line forms the base of the ninth triangle (Δ9, Brihaspati) with its apex pointing down and its apex is located in the middle of chord DE.

8. Identify the point of intersection between the base of the ninth triangle and the side of the triangle with apex at I and its base a horizontal through H. Draw a line through this point and the inner triple intersection point on chord BC and identify the point of intersection with the *brahmasutra* axial diameter. With this point as apex and the line as its side, complete the triangle (Δ6, Ketu) with its base line through J.

**Figure 13: Drawing the last triangles using 13.330 and 136.660 angles**

9. Draw a horizontal through the point of intersection of the sides of the triangle DFE (Δ2) and the sides of the triangle with its base drawn through J (Δ6). Complete the fifth triangle with its apex at H (Δ5, Rahu).

10. With a horizontal through the apex of the triangle that has its base through J (Δ6), draw the base for the next triangle. Its apex is given by the intersection of the base of the triangle (Δ5 completed in step 9 above). This is Δ7 (Budha).

11. The last triangle (Δ8, Sukra) is drawn with base horizontal joining the intersections of sides of Δ6 and Δ7 and its apex at the center of the base Δ4.

All the triangles that make the five *Shakti-chakras* and the four *Siva-chakras* are thus drawn. There will be no error at any triple intersection.

All the angles proposed are also critical in depicting time and its renewal cycles and their asymmetry energise the diagram. With the triangles indicating relative movement of the planets in the solar system, Sun and Moon and Ketu (Dragon’s tail, descending or northern mode) and Rahu (Dragon’s head, ascending or southern mode) as seen from earth against the Rasi and the Naxatra circular scale of universe, the diagram assumes truly the form of universe defined by time and seasonality as per *ganitajyotish.* It is a true mathematical icon of ortho-centric view of the time and space phenomena of the universe of our sun.

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1. Other descriptions of *Sriyantra* omit the three rings and the three lines as circuits and still others have variations in the way the rings or lines are laid out - reflecting loss of meaning of these circuits over time. The loss also caused the eclipse of basic clues to drawing a correct Sri Yantra apparently hidden there. [↑](#endnote-ref-1)
2. This distinction of Chakra as just the diagram component of an Yantra should be noted as suggested by its title, Sri Chakra, this article will dwell on the Sri Chakra, the diagram, rather than the Sri Yantra in totality. [↑](#endnote-ref-2)
3. Sumatitantra, a Lichchhavi period document from Kathmandu, *folio 14a-14b*, states … *vano guna 800 bhagnadi bhaga 292207…,* which provides the measure of 292207/800 or 365.25875 *savan* days to a solar year as observed from earth. [↑](#endnote-ref-3)
4. For ‘Archimedes’ method’ of trisecting an angle see, www. jimloy.com/geometry/trisect.htm. [↑](#endnote-ref-4)
5. Hindus used a parallel system of subdivisions for time and spherical space cf. 21600 *kala* in the circular angle of 360 *amsa* (1 *amsa* = 60 *kala*, 1 *kala* = 60 *vikala* and 1 *vikala =* 60 *prati-vikala*) and one *amsa* is made of 216000 *prati-vikala*. [↑](#endnote-ref-5)
6. In relation to the bounding lines of the first quadrant, angle 400 as measured from one ray becomes 500 from the other bounding ray and the latter’s tripling twice will result in angle of 4500, the angle making 5 quadrants. [↑](#endnote-ref-6)
7. In this cult, the residual energy of the diagram is female or Sivayuvati *tattva*. [↑](#endnote-ref-7)
8. Here, the residual energy of the diagram is male or Siva *tattva*. [↑](#endnote-ref-8)
9. In the third instruction Shastri’s transliteration provides the rub off portions for first and ninth chords as 3 each. Dabral’s articlegives the measure as 5 units each. [↑](#endnote-ref-9)
10. An algorithm linking the error at the triple intersections on the 6th chord and programming for incremental adjustment of data of the selected chord (say by shifting the chord up or down at the rate of 1/100 of the unit at a time) to get area of triangle at the intersections as zero can be made. Also AutoCad could be used to check accuracies up to eighth place of decimal! [↑](#endnote-ref-10)
11. This is drawn from the use of term *kranti* for *jya* by Ganesh Daivagya as for the circle of radius 24, approximate height of *jya* is 6 and the angle inclination of Sun is 60 when its elevation is 150. [↑](#endnote-ref-11)
12. The only other significant study was made in 1984 by Dr. Alexei Kulaichev of Moscow State University, which attempted to construct an algorithm and use the then computers to solve the twenty-four triple intersections through the ‘traditional mathematics’ of property of circle elaborated through algebraic and trigonometric equations and calculations using the data of chords, rises and partial cords as given in ancient literature (Shastri and Iyenggar). As I have not been able to locate the full report and have only read short references to it in some internet sites and Kalyan, an Indian religious magazine. Apparently, the capacity of the computers used by him could not provide the memory for the very large number of iterations it had to perform to solve the twenty-seven algebraic equations with variables referred by further linear and circular equations. He apparently did not present a practical algorithm but ended up concluding that even though the application of modern mathematics can theoretically describe the construction, the computation itself is impossibly lengthy. “For the first step of transformation (from four required ones) a computer must perform more than 1011 operations and each succeeding step requires, at least, 100 times more operations than the preceding one. Moreover, the operations require handling of numbers with as many as 4 thousand figures. These demands very far exceed the capacities of modern computers.” Kulaichev suggested that the achievement of such geometrical constructs in Indian mathematics may indicate 'the existence of unknown cultural and historical alternatives to mathematical knowledge, e.g. the highly developed tradition of special imagination'! If Kulaichev had referred to the tables of chords and rises prepared by ancient mathematicians, he may not have worried about unknown cultural and historical alternatives to mathematical knowledge. [↑](#endnote-ref-12)
13. Fonseca has listed some of the western classic angles measuring close to these e.g. larger acute angle of the 3-4-5 Pythagorean triad = 53007’48.37”, heptagon angle = 51025’42.86”, base acute angle of Kepler’s triangle = 51049’38.25” [↑](#endnote-ref-13)
14. Fonseca R, Stonehenge: Aspects of Ad Quadratum Geometry, *Journal of Architecture and Planning Research* 12:4 (Winter, 1995) pp. 357-365. [↑](#endnote-ref-14)