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Understanding the geometry of Sri Chakra

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Abstract
Sri Chakra, also known as Sri Yantra is the most profound geometric symbolism in Hindu philosophy and spiritual practices. The inner part of the Chakra is made up of 43 triangles arranged in five concentric rings, all arising from nine intermeshing isosceles triangles inside a circle. This paper reviews previous models of Sri Chakra's geometry and proposes a new and simpler model for understanding its geometry. It also presents a simpler method for constructing a valid Sri Chakra. A novel method for naming the various lines and triangles in the Sri Chakra is also presented for ease of understanding its geometry. A proof of the validity of the constructed Sri Chakra is included.

Keyword: Sri Chakra, geometry, modelling, Marma Sthana

Introduction
What is Sri Chakra?
Sri Chakra or Sri Yantra is one of the most sacred designs in Hindu religion, yoga and tantric practices [1, 2, 3, 4]. It is worshipped as Goddess Lalita Tripurasundari Devi. It has a variety of significations across various dimensions of ancient art, culture, music, cosmology, worship, spirituality, philosophy, yoga and tantric practices.

In modern literature it has been described as "an under-determined Euclidean Plane Geometry Problem" [5]. However, its true structure is coded in Sri Vidya Ratna Sutram [10] in cryptic sutra form as:

> कगजदशारद्वयमन्वस्त्राष्टदलस्वरपत्रत्रिवृत्तभूबिम्बसंज्ञाकथितं श्रीसदनम् |
> ka-ga-ja-dashaara-dvaya-manvastra-ashta-dala-svara-patra-trivritta-bhoo-bimba-sanjnaa-kathitam srisadanam.

which when decoded translates to: "1-3-8-pair of 10-sided figures-14-sided-8-petal-16-petal-3-circles-earth-image signed design is called Sri Sadanam."

Figure 1 shows a traditional Sri Chakra on copper (brought by the author from Varanasi, India). Its outer elements, namely the Bhu-pura enclosure, 3-concentric circles and the 8- and 16-petals are fairly easy to understand and construct. The inner parts are the most interesting ones being made up of 43 triangles enclosed in a circle as follows (Fig. 2):

- An outer Chakra (ring) of 14 triangles called SarvaSaubhagyadayakaChakra
- Two Chakras (rings) of 10 triangles each called SarvarthaSadhakaChakra and Sarva Rakshakara Chakra
- One Chakra (ring) of 8 triangles called SarvaRogaharaChakra, and
- One innermost triangle.

In the middle of the innermost triangle is the dot "Bindu" which represents "the centre of everything."

These 43 triangles are made from only 9 intersecting isosceles triangles - 4 upward facing and 5 downward facing. The entire design has left-to-right symmetry but not vertically. The Bindu is not exactly at the centre of the circle.

Previous models of Sri Chakra Geometry

The geometry of Sri Chakra has been described in the Upanishads in cryptic forms [11, 12]. It has also been studied widely in modern literature from a variety of disciplines including mathematics, computer science, theology and religion.

Huet's model

Huet's model [5] views Sri Chakra as a geometric optimisation problem with four or more parameters which when optimised using numerical computational methods, leads to a "classical Sri Chakra" with better symmetry and aesthetics. Huet states:
Theorem: Sri Yantra is an under-determined Euclidean plane geometry problem with 4 real parameters, admitting an infinity of solutions around the Classical Sri Yantra.

Definition: Classical Sri Yantra is defined by: YF = 0.668, XF = 0.126, YP = 0.463, XA = 0.187, YJ = 0.398, YL = 0.165, YA = 0.265, YG = 0.769, YV = 0.887, YM= 0.603, YD = 0.551.

Here, some of the letters A-Z denote right corners of triangles, some others top or bottom corners and yet others denote points of intersections of lines, with no facility to either systematically denote or remember them in any order. It is not clear if this indeed is the best way to model or construct a Sri Chakra. More importantly, this model with so many real numbers to the third decimal place is unlikely to have been how the concept of Sri Chakra developed and how it has been put to practice over a thousand years (at least). There must be a simpler description of the geometry of Sri Chakra that enables anyone to draw, sketch, paint, etch, sculpt or otherwise geometrically construct a valid Sri Chakra.

Lakshmidhara's Srishti Krama model

In this model which Lakshmidhara outlines in his commentary on the well-known hymn Soundaryalahari [13], the vertical diameter of the outer circle is divided into 48 equal parts. Horizontal lines are drawn at the 6th, 12th, 17th, 20th, 23rd, 27th, 30th, 36th and 42nd divisions to form the bases of the nine triangles. However, the widths of the lines are not easily definable. We are supposed to rub off 3 units at either end of the 6th line; 5 units on the 12th; 16 on the 20th; 18 on the 23rd; 16 on the 27th; 4 units on the 36th; 3 units on the 42nd line.
There have been attempts also to empirically fix the coordinates of the endpoints of these lines [9]. Others have tried to model Sri Chakra using a set of algebraic non-linear equations up to the 16th power [7]. Attempts have also been made to apply a model of circles [8] and the idea of Golden Ratio to determine the proportions of the triangles in Sri Chakra [6, 9].
A common feature of the above models is their rather high complexity which raises the question how such a complex geometry could have been practiced across India, constructed easily using materials such as coloured powders, etched or embossed on copper, silver and gold sheets and even carved in stone in various Temples across India. There must be a simpler way to explain, understand and construct the geometry of Sri Chakra.

A Simpler Model

Requirements for a Sri Chakra model

- It should work for Sri Chakra of any size;
- It should have few empirical parameters;
- The parameters should be based on simple ratios that are easy to remember, calculate and construct;
- It should be possible to calculate the various proportions using simple integer arithmetic only; and
- Line intersections called Marma Sthanas must be perfect.

Importance of Marma Sthanas

The last point about line intersections leads to the concept of Marma Sthanas which are central to the design and practice of Sri Chakra. Points where three lines intersect are called Marma Sthanas (Fig. 3). There are exactly 18 such intersections (M1 to M18). It is important that each of them is an exact intersection, i.e., with no gap or small triangle being formed by any misalignment of the three lines with respect to each other.

Nomenclature

There are nine triangles that constitute the essential geometry of Sri Chakra. We propose a new nomenclature for understanding the geometry of Sri Chakra by mapping the nine triangles to the concept of NavaGrahas - the nine grahas ("planets" or astronomical bodies in the solar system including the Sun, the Moon and the two lunar nodes, the two points of intersection of the Earth's and Moon's orbits). Use of these nine grahas is common to much of Hindu spirituality and astrology. Thus, the nine triangles are proposed to be named Ravi (Sun), Chandra (Moon), Kuja (Mars), Budha (Mercury), Guru (Jupiter), Shukra (Venus), Shani (Saturn), Rahu and Ketu, the last two being the lunar nodes.

Sri Chakra Definition

The geometry of a valid Sri Chakra can be defined using the above nomenclature as follows:
A set of nine isosceles triangles Ravi, Chandra, Kuja, Budha, Guru, Shukra, Shani, Rahu and Ketu inside a circle each having one side parallel to the horizontal, arranged from top to bottom such that each is left-right symmetrical with respect to the vertical diameter of the circle, and:

- Kuja and Shani triangles touch the circle at all three vertices; no other triangle touches the circle but instead has its upward/downward vertex touching the horizontal edge of another triangle,
- The five triangles Ravi, Chandra, Kuja, Budha and Guru are pointing downwards and the other four Shukra, Shani, Rahu and Ketu are pointing upwards,
- The 9 triangles intersect in sets of 3 at exactly 18 points - the Marma Sthanas M1 to M18 (Fig. 3),
- 43 non-overlapping triangles are formed in "concentric" chakras (rings) of 14 (being the outermost), 10, 10, 8 triangles and a single innermost downward pointing isosceles triangle whose centre - called Bindu - is somewhat above the centre of the circle,
- And in the chakras of 14, 10, 10 and 8 triangles, each triangle meeting another triangle on either side exactly at one vertex like jewels in a garland.

Outside this cirlce, Sri Chakra has a ring of 8 petals - Ashtadala, a ring of 16 petals - Shodhashadala and a square construct known as Bhoopura. The geometry of these constructs are quite straightforward.
Tables 1 and 2 show the Marma Sthanas and the angles and coordinates of all the triangles. It may be noted from Table 1 that Ravi triangle has 8 MarmaSthanas on it; Chandra triangles has 6; Kuja triangle has 8; Budha triangle has 4;

Guru triangle has 2; Shukra triangle has 4; Shani triangle has 8; Rahu triangle has 6; and Ketu triangle has 8. (Total of these numbers is 54 = 18 x 3.) It may be noted from Table 2 that no triangle has its tip on Budha and Guru lines. It may also be noted that for the sample diameter d = 360 mm taken in Table 2, x coordinates range from -180.0 to +180.0 while y coordinates range from 0.0 to 360.0.

A Method of Construction: Marma Sthana Method

The proposed new method of construction ensures that the Marma Sthana intersections are obtained with perfection, by focusing on drawing lines to systematically create the intersections M1-M18 rather than on fixing the coordinates corners of the triangles as done in previous methods.

Parameters

- Size d, the diameter of the main inner circle of Sri Chakra (taken as 360 mm for convenience in Figs. 4 and 5).
- Height of placement of Kuja line: 2/3 d
- Heigh of placement of Shani line: 2/5 d
- Height of placement of Ravi line: 8/9 d
- Height of placement of Ketu line: 1/6 d
- Placement of Bindu: Height of Shani line + 1/8 d

For instance, if the diameter of the circle d = 360 mm, then the above heights would be 240, 144, 320, 60 and 189 mm respectively. These parameters can be remembered easily by constructing a verse in Sanskrit such as:

रविरष्टनवांशे स्यात् त्र्यंशद्वये तु मङ्गलः ।
पञ्चमांशद्वये शनिः षष्ठांशे नवमो ग्रहः ।
मध्ये च बिन्दुरष्टांशे श्रीचक्रस्य एवं क्रमः॥

Steps in Constructing a Sri Chakra (see Fig. 4)

A step-by-step procedure for constructing a Sri Chakra with the above paramaters:

Step 1: Draw a circle of desired diameter d and draw its vertical diameter.

Step 2: Draw Kuja and Shani horizontal lines at heights 2/3 d and 2/5 d respectively.

Step 3: Complete the Kuja triangle (downward) and Shani triangle (upward) with their tips touching the circle on the vertical line.

Step 4: Draw Ravi and Ketu lines at heights 8/9 d and 1/6 d respectively.

Step 5: Draw the two slanting edges of the downward Chandra triangle resting at the centre of Ketu line and passing through the points of intersections of Kuja line with Shani triangle, thereby forming the two Marma Sthanas M3 and M6.

Step 6: Draw the two slanting edges of the upward Rahu triangle coming down from the centre of the Ravi line and passing through the points of intersection of Shani line with Kuja triangle, thereby forming the two Marma Sthanas M13 and M16.

Step 7: Complete the upward Ketu triangle reaching the centre of the Kuja line with its slanting lines passing through the points of intersection of Shani line with the two lines drawn in Step 5, thereby forming the two Marma Sthanas M14 and M15.

Step 8: Complete the Rahu triangle by drawing the horizontal lines passing through the points of intersection of Kuja and Ketu triangles, thereby forming the Marma Sthanas M17 and M18.

Step 9: Mark the Bindu at height (Shani line) 2/5 d + 1/8 d.

Step 10: Mark the Shukra line as midway between the Bindu and Shani line, i.e., at 2/5 d + 1/16 d.

Step 11: Draw the downward Ravi triangle from the Ravi line by passing through the points of intersection of the Kuja line with the Rahu triangle, thereby forming the Marma Sthanas M4 and M5, the two lines meeting at the Shukra point.

Step 12: Draw the horizontal Chandra line through the points of intersection of the Ravi and Shani triangles thereby forming the Marma Sthanas M1 and M2 and completing the Chandra triangle.
At this point, the six outer triangles - three upward and three downward - are complete.

Step 13: Draw the horizontal Shukra line extending to the edges of the Chandra triangle. Complete the Shukra triangle, reaching upward to the Chandra point.

Step 14: Draw the Guru line as the horizontal passing through the points of intersection of Ravi and Ketu triangles, thereby forming the Marma Sthanas M9 and M10, the Guru line extending up to the edges of the Shukra triangle. Complete the downward Guru triangle reaching down to the Shani point.

Step 15: Draw the Budha line as the horizontal passing through the points of intersection of Ravi and Shukra triangles thereby forming Marma Sthanas M7 and M8, the Budha line extending up to the Rahu triangle.

Step 16: Complete the downward Budha triangle to reach down to the Rahu point (Fig. 5).

The final set of 43 triangles along with numbers to indicate the rings is shown in Fig. 5. It is most important that, if the entire construction has been done correctly, the lines of the Budha triangle shall pass through the points of intersection of Shukra line and Ketu triangle thereby forming the remaining two Marma Sthanas namely M11 and M12.
It may be noted that the outer 8-petal ashtadala and 16-petal shodashadala, the three concentric circles as well as the square outline called Bhupura have simple geometry and are easy to draw. This method has been implemented in a computer program using Python Turtle and used to generate Figures 3-5.

Theorem: The Sri Chakra constructed by the Marma Sthana Method is valid.

Proof: A Sri Chakra is valid if it meets the definition and in particular if all the intersections among the triangles are proper. The Marma Sthana Method ensures that the desired number of isosceles triangles are constructed. It further ensures by its very method of drawing a third line through an existing intersection of two other lines that Marma Sthanas M1 through M10 and M13 through M18 are proper intersections of three lines. The resulting Sri Chakra is valid if the remaining two Marma Sthanas M11 and M12 (formed by the intersections of Ketu, Budha and Shukra triangles) are proper.

Applying the geometry and trigonometry of the various triangles constructed by the method, we can easily derive the angles of all the triangles as well as the coordinates of all their corners. These are shown in Table 2 (for a diameter d = 360 mm). The calculations (shown in the Appendix) have been implemented and verified using a spreadsheet as well as a Python computer program.

The coordinates of Marma Sthanas M1 through M10 and M13 through M18 can also be derived and are shown in Table 1 (for the diameter d = 360 mm). We now derive the coordinates of M11 and M12 separately from Ketu and Budha triangles as follows:

From Ketu triangle: M11.x = (240.0 - 166.5) tan (25.47) = -35.01 mm

From Budha triangle: M11.x = (166.5 - 96.59) tan (26.56) = -34.93 mm

In other words, the left sides of the Ketu and Budha triangles intersect the Shukra lines at x = -35.01, y = 166.5 and x = -34.93, y = 166.5 mm respectively. The left sides of Ketu and Budha triangles can also be represented by the equations (derived from the data in Table 2):

$$y = 240.0 + 2.09962\, x \text{ and } y = 96.59 - 2.00117\, x$$

Respectively while the Shukra line itself is y = 166.5. Solving these, we get the two values for x as -35.01 and -34.93 mm which are once again close enough to form Marma Sthanas M11 and M12.

The error in the x coordinates (which equals 0.02% of the diameter d) is within acceptable limits considering the thickness of lines drawn to construct the Sri Chakra. For instance, with a 300 DPI (dots per inch) resolution, the difference in M11.x values is less than one dot. It may also be noted that the method of construction as well as the angles of all the triangles are independent of the diameter d.

Thus the constructed Sri Chakra is valid.

Corollary: Rahu triangle is equilateral.

It can be seen from the angles of the triangles shown in Table 2 that only the Rahu triangle is an equilateral triangle.

Table 1: Eighteen Marma Sthanas and Their Coordinates

Marma Sthanas	On Line	With Intersection of	Coordinates (for d = 360 mm)
M1 and M2	Chandra	Ravi and Shani triangles	M1 = (-68.79, 275.75) and M2 = (68.79, 275.75)
M3 - M6	Kuja	Chandra and Shani triangles (outer ones) and Ravi and Rahu triangles (inner ones)	M3 = (-97.98, 240.0) and M6 = (+97.98, 240.0) M4 = (-46.28, 240.0) and M5 - (46.28, 240.0)
M7 and M8	Budha	Ravi and Shukra triangles	M7 = (-31.46, 216.46) and M8 = (31.46, 216.46)
M9 and M10	Guru	Ravi and Ketu triangles	M9 = (-19.93, 198.15) and M10 = (19.93, 198.15)
M11 and M12	Shukra	Budha and Ketu triangles	M11 = (- 35.01, 166.5) or (-34.93, 166.5) and M12 = (35.01, 166.5) or (34.93, 166.5)
M13 - M16	Shani	Kuja and Rahu triangles (outer ones) and Chandra and Ketu triangles (inner ones)	M13 = (-101.82, 144.0) and M16 = (+101.82, 144.0) M14 = (-45.72, 144.0) and M15 = (+45.72, 144.0)
M17 and M18	Rahu	Kuja and Ketu triangles	M17 = (-68.30, 96.59) and M18 = (+68.30, 96.59)

Table 2: Angles and Corners of the Nine Triangles (coordinates are for d = 360 mm)

Triangle	Upward/Downward	Top	Bottom	y	Left Corner	Right Corner	Left/Right Angles	Top/Bottom Angle	Marma Sthanas
Ravi	Down	Ravi	Shukra	320	-96.66	96.66	57.8	64.4	M1, M2, M4, M5, M7, M8, M9, M10
Chandra	Down	Chandra	Ketu	275.75	-117.44	117.44	61.44	57.12	M1, M2, M3, M6, M14, M15
Kuja	Down	Kuja	Circle	240	-169.71	169.71	54.74	70.53	M3, M4, M5, M6, M13, M16, M17, M18
Budha	Down	Budha	Rahu	216.46	-59.90	59.90	63.45	53.11	M7, M8, M11, M12
Guru	Down	Guru	Shani	198.15	-41.18	41.18	52.75	74.5	M9, M10
Shukra	Up	Chandra	Shukra	166.5	-57.97	57.97	62.05	55.91	M7, M8, M11, M12
Shani	Up	Circle	Shani	144	-176.36	176.36	50.77	78.46	M1, M2, M3, M6, M13, M14, M15, M16
Rahu	Up	Ravi	Rahu	96.59	-129.25	129.25	59.95	60.1	M4, M5, M13, M16, M17, M18
Ketu	Up	Kuja	Ketu	60	-85.93	85.93	64.53	50.94	M9, M10, M11, M12, M14, M15, M17, M18

Fig 1: Traditional Sri Chakra from Varanasi, India

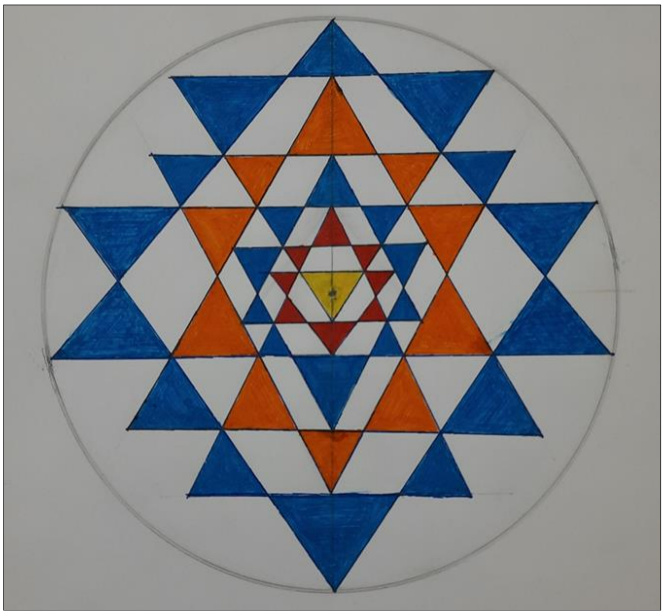

Fig 2: The five rings with 43 triangles

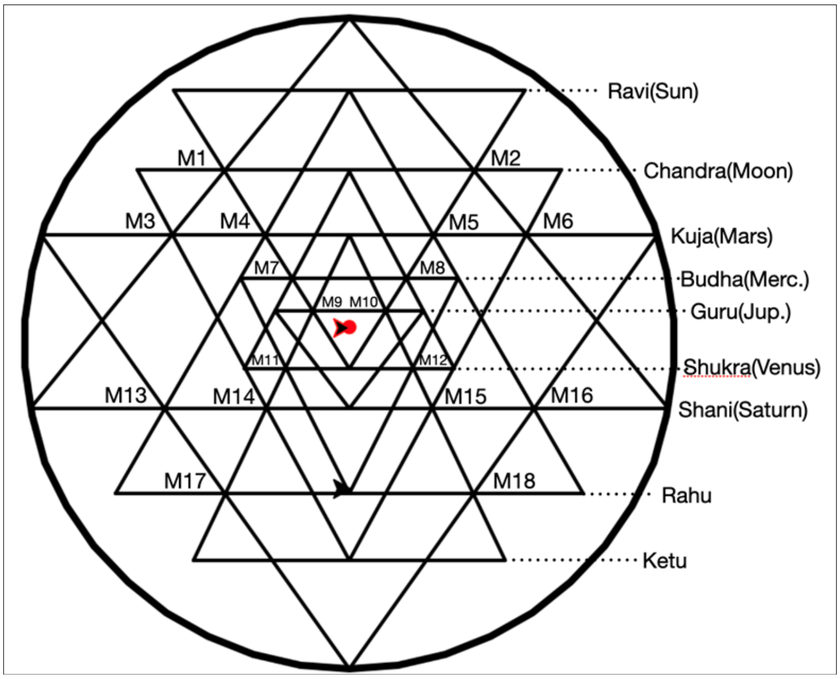

Fig 3: Marma Sthanas M1-M18

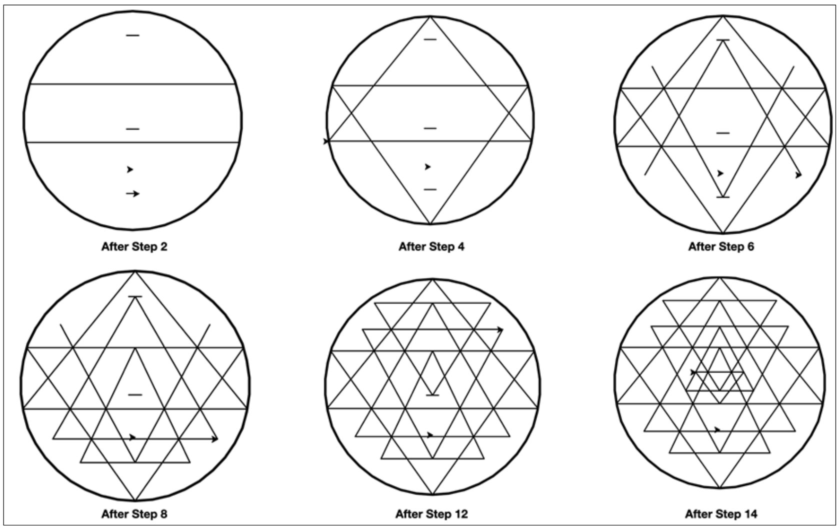

Fig 4: Sri Chakra Construction Steps

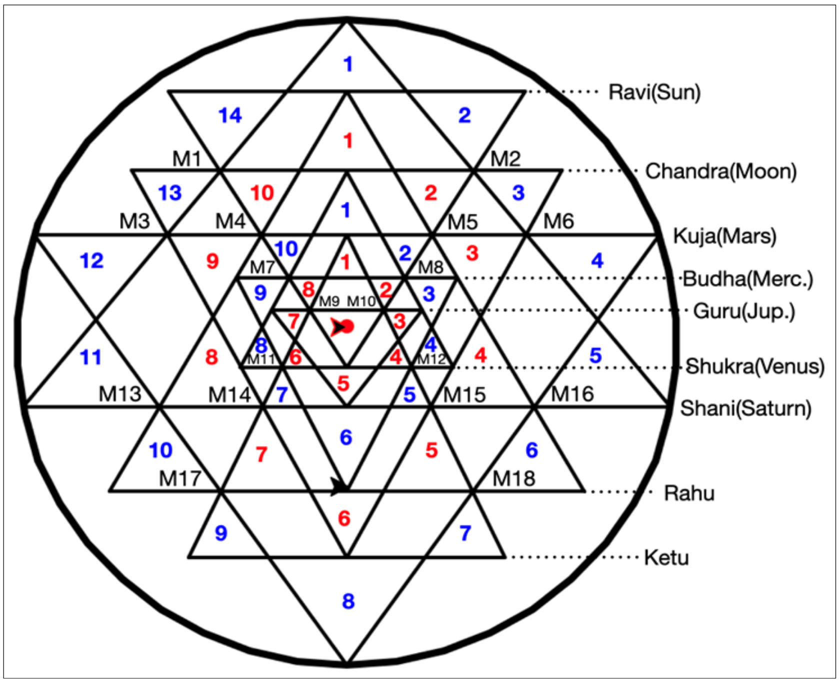

Fig 5: Completed Sri Chakra Triangles with Numbers

Summary

This work provides a simpler model of the geometry of Sri Chakra that not only helps us understand how the various triangles intermesh to create a valid Sri Chakra but also enable us to draw or otherwise make a valid Chakra using simple proportions. It also introduces a novel way of naming the various lines and triangles using the nine grahas to help us understand and remember the geometry of the Chakra. A proof of the validity of the method of construction is also provided. Further work is needed to explore the mappings of the various parts of the Sri Chakra to various models in art, music, language and spiritual studies.

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Appendix: Triangle Calculations

Let the diameter be d; Let TANHalf(Tr) denote the TAN() of half of the top/bottom angle of the triangle Tr;

Ravi.y = 8 * d / 9; Kuja.y = 2 * d / 3; Shani.y = 2 * d / 5; Ketu.y = d / 6;
Bindu.y = Shani.y + (d / 8); Shukra.y = (Bindu.y + Shani.y) / 2;

ShaniSinAngle = SIN^{-1}((d/2 - Shani.y) * 2 / d);
Shani.x = (d/2 - Shani.y) / TAN(ShaniSinAngle);
ShaniLeftAngle = TAN^{-1}((d - Shani.y) / Shani.x) * 180 / π;
ShaniTopAngle = 180 - 2 * ShaniLeftAngle;

M3.x = -(d - Kuja.y) / TAN(ShaniLeftAngle); M6.x = - M3.x;

KujaSinAngle = SIN^{-1}((Kuja.y - d/2) * 2 / d);
Kuja.x = (Kuja.y - d / 2) / TAN(KujaSinAngle);
KujaLeftAngle = TAN^{-1}(Kuja.y / Kuja.x) * 180 / π;
KujaBotAngle = 180 - 2 * KujaLeftAngle;

M13.x = -Shani.y / TAN(KujaLeftAngle); M16.x = - M13.x;

RahuLeftAngle = TAN^{-1}((Ravi.y - Shani.y) / M16.x) * 180 / π;
RahuTopAngle = 180 - 2 * RahuLeftAngle;

M4.x = -(Ravi.y - Kuja.y) * TANHalf(Rahu); M5.x = - M4.x;

ChandraBotAngle = TAN^{-1}(M6.x / (Kuja.y - Ketu.y)) * 180 * 2 / π;
ChandraLeftAngle = (180 - ChandraBotAngle) / 2;

M14.x = -(Shani.y - Ketu.y) * TANHalf(Chandra); M15.x = - M14.x;

KetuTopAngle = TAN^{-1}(M15.x / (Kuja.y - Shani.y)) * 180 * 2 / π;
KetuLeftAngle = (180 - KetuTopAngle) / 2;

M17.y = Kuja.y * TANHalf(Ketu) / (TANHalf(Kuja) + TANHalf(Ketu));
Rahu.y = M17.y; M17.x = -M17.y * TANHalf(Kuja); M18.x = - M17.x;
Rahu.x = (Ravi.y - Rahu.y) * TANHalf(Rahu);
Ketu.x = (Kuja.y - Ketu.y) * TANHalf(Ketu);

RaviBotAngle = 2 * TAN^{-1}(M5.x / (Kuja.y - Shukra.y)) * 180 / π;
RaviLeftAngle = (180 - RaviBotAngle) / 2;
Ravi.x = (Ravi.y - Shukra.y) * TANHalf(Ravi);

M1.y = (d * TANHalf(Shani) + Shukra.y * TANHalf(Ravi)) / (TANHalf(Shani) + TANHalf(Ravi));
Chandra.y = M1.y; M1.x = -(M1.y - Shukra.y) * TANHalf(Ravi); M2.x = - M1.x;

Chandra.x = (Chandra.y - Ketu.y) * TANHalf(Chandra);

Shukra.x = (Shukra.y - Ketu.y) * TANHalf(Chandra);
ShukraTopAngle = 2 * TAN^{-1}(Shukra.x / (Chandra.y - Shukra.y)) * 180 / π;
ShukraLeftAngle = (180 - ShukraTopAngle) / 2;

M9.y = (((Shukra.y * TANHalf(Ravi)) + (Kuja.y * TANHalf(Ketu))) / (TANHalf(Ravi) + TANHalf(Ketu));
Guru.y = M9.y; M9.x = -(M9.y - Shukra.y) * TANHalf(Ravi); M10.x = - M9.x;

Guru.x = (Chandra.y - Guru.y) * TANHalf(Shukra);
GuruBotAngle = 2 * TAN^{-1}(Guru.x / (Guru.y - Shani.y)) * 180 / π;
GuruLeftAngle = (180 - GuruBotAngle) / 2;

M7.y = (((Chandra.y * TANHalf(Shukra)) + ((Shukra.y * TANHalf(Ravi))) / (TANHalf(Shukra) + TANHalf(Ravi));
Budha.y = M7.y; M7.x = -(Chandra.y - M7.y) * TANHalf(Shukra); M8.x = - M7.x;

Budha.x = (Ravi.y - Budha.y) * TANHalf(Rahu);
BudhaBotAngle = 2 * TAN^{-1}(Budha.x / (Budha.y - Rahu.y)) * 180 / π;
BudhaLeftAngle = (180 - BudhaBotAngle) / 2;

From Ketu triangle:
M11.x = -(Kuja.y - Shukra.y) * TANHalf(Ketu); M12.x = - M11.x;

From Budha triangle:
M11.x2 = -(Shukra.y - Rahu.y) * TANHalf(Budha); M12.x2 = - M11.x2;