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ORIGIN OF THE MOVING ECCENTRIC CIRCLE PLANETARY MODEL IN INDIA

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It is argued that the moving eccentric circle model of planetary motions might have been first put forward in India for explaining the planetary phenomena. Using the Ṛgvedic data about synodic periods of planets it is demonstrated how it gives rise to 7-tiered cosmos consisting of 7 regions (*lokas*).

Key words: Solar and lunar constant, Vedic sidereal period, Vedic synodic period, Eccentric model, Vedic cosmos.

VEDIC ASTRONOMY OF THE SUN AND THE MOON

In ancient India, astronomy was used for devising a seasonal calendar for conducting economic and social activities like hunting, fishing, cultivating, harvesting etc. The calendar was regulated with a series *yajñas* (sacrifices) which gave them a religious character and produced a class of astronomer-priests or (*jyotirvids*).

We have described the earliest Vedic calendar and its later development in an INSA project report [1] and other publications [2,3,4]. Throughout the Vedic period the year was started on winter solstice day. So it was possible to trace the history of the Vedic calendar from 7000 B.C. to 1500 B.C. [5] by noting the shift of the winter solstice due to precession. The successive steps in the refinement of the calendar with time were:

(i) A solar year of 364 to 366 days controlled by the yearlong *Gavāmayanam* sacrifice of 360 days followed by 4,5 or 6 days of *pravargya*

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and *upāsad* days of concecration. From the story of *pravargya* and the praise of *Aśvinīkumārs* during that ceremony it is evident that winter solstice was heralded by the heliacal rising of *Aśvini nakṣatra* (around 7000 BC).

(ii) When it was realized that the year contained close to 365 days one used a 6-year *yuga* consisting of 6 years of 360 days followed by an *adhikamāsa* (intercalary month) of 30 days. This follows from the Śunassepha legend in *Śatapatha Brāhmaṇa*.According to it, Hariścandra's son Rohita, who represented the rising sun of the winter solstice, avoided death by wandering for 6 years, and he was replaced by Śunassepha (*adhikamāsa*) at the end of 6 years.

(iii) After noting that the synodic period of the moon is nearly 29½ days from the performance of *Darśa-Pūrṇamāsa yaṣtis* (new moon and full moon sacrifices) the *Gavāmayanam* sacrifice was replaced by *Utsarajinamayanam* sacrifice consisting of 12 lunar months followed by 11 *atirātra* days for completing the year of seasons. This occurred around 6000 BC when the winter solstice coincided with the *Caitri* full moon.

(iv) Concept of a nominal 5-year *yuga* consisting of 62 lunar months spanning 5 years of 12 lunar months with an additional lunar *adhikamāsa* at the end of the 3rd and 5th years so that the year always started on *śukla-pratipada*. This occurred around 4000 BC when the winter solstice coincided with *phālguni paurṇimā*.

(v) After the discovery of *nakṣatras* (asterisms) and the knowledge of the sidereal period of the moon, the 5-year yuga was modified by having *adhikamāsa* at the end of each 30 months period. It consisted of 62 synodic lunar months and 67 sidereal months of about 27⅓ days.

(vi) Correction of the 5-year yuga by the 30-year *Dākṣāyaṇīya* sacrificial calendar in which the last *pakṣa* (half month) of the *adhikamāsa* at the end of 15th and 30th year were dropped as *kṣayapakṣas*. Alternatively, the whole *adhikamāsa* at the end of the 30th year was dropped as *kṣayamāsa*. *Mahāśivarātri* festival was introduced at this time (around 3000 BC) for ensuring that the solar *nakṣatra* was *śkaṭabhiṣag* at the beginning of the year.[6]

(vii) Final correction with *agnicayana-vidhi* of 95 years consisting of 3 *Dākṣāyaṇīya* sacrifices and one nominal 5-year yuga, most probably was adopted around 2000 BC.

(viii) Formulation of the mathematical rules by sage Lagadha was introduced around 1400 BC for the 5-year, 30-year and 95-year cycles.

All these calendars were based on the mean rates of motions of the Sun and the Moon among the *nakṣatras*. The improvement in their accuracy with time is illustrated in Table 1.

Table 1: Improvement in solar and lunar constants

Calendar	6-yr yuga	5-yr yuga	30-yr cycle	95-yr cycle
Epoch (BC)	7000-5000	4000	3000	2000
No. of days	2190	1830	10956	34699
Year (*tithis*)	371	372	371	371,05*
Year (days)	365	366	365.2	365.25*
Syn. Month(days)	29.5	29.516	29.531	29.531*
Sid. Month(days)	----	27.313	27.322	27.322*

*The modern values are: Tropical year 365.2422 days = 371.048 tithis; Sidereal year 365.2564 days, Synodic month 29.5306 days and Sidereal month 27.3417 days.

Planetary Phenomena and Eccentric Circles

(a) **Synodic periods of the planets**: It may be noted that the synodic period of the moon was discovered first on account of the repetition of the phases of the moon. Only when it was found that the successive full moons are separated by about 2¼ *nakṣatras* that it was realized that the sidereal period of the moon is about 2 1/5 days shorter than the synodic period. As the sun is opposite to the moon on full moon days it was also clear that the sun moved about 2¼ *nakṣatras* in a synodic month, which gave a better value for the length of the year.

In the case of planets it is their aspects with respect to the Sun that would have been noticed first like the phases of the Moon. The planets Mercury and Venus pass through the phenomena of superior conjunction, eastern elongation, inferior conjunction, western elongation and back to superior conjunction. Similarly, the planets Mars, Jupiter and Saturn undergo conjunction, western quadrature, opposition, eastern quadrature and back to conjunction. It would have been easy to note the interval between each of the same phenomenon, which is known as the synodic period of the planet. It should, therefore, be no surprise that the Vedic astronomer-priests knew their values as claimed by S. Kak.[7] Vedas contain hymns composed over a long period of several thousand years. But they were most probably compiled in their present form in the 2nd millennium BC. So it would have been possible to encode astronomical data in the method of compilation. According to Kak the synodic periods of planets are encoded as numbers of hymns (days) in various *maṇḍalas* of *Ṛgvedas*. They are given in Table 2 with some modifications in his groupings in the case of Mercury and Venus.

Table 2. Vedic synodic periods of planets

Planet	(*Maṇḍala*) hymns	Total (days)	Modern (days)
Mercury*	$\frac{(2)43 = 43}{(6)75 = 75}$	118	115.9
Venus**	$\frac{(2)43(7)104 = 147}{(4)58(10)191(1)191 = 440}$	587	583.9
Mars	$\frac{(9)114(8)92 = 206}{(5)87(7)104(10)191(1)191 = 573}$	779	779.9
Jupiter	$\frac{(3)62(9)114 = 176}{(2)43(5)87(8)92 = 222}$	398	398.9
Saturn	$\frac{(4)58(9)114 = 172}{(5)87(6)75(2)43 = 205}$	377	378.1

* For Mercury Kak's (3)62(4)58 replaced by (2)43(6)75 and total changed from 120 to 118.
** For Venus, Kak's (1) 191, (5)87, (9)114, (10)191 replaced by (1)191, (2)43, (7)104, (4)58, (10)191 and total changed from 583 to 587.

(b) **Sidereal periods of planets:** From the data of Table 2 it is easy to find the sidereal periods of planets. If S is the synodic period in days and Y is the number of days in a year, then the planet moves through an arc of S ± Y days when the sun moves through an arc of S days. So the sidereal period of the planet will be S/(S± Y) years. Here plus sign holds for planets Mercury and Venus which move faster than the Sun; and minus sign applies to planets Mars, Jupiter and Saturn which move slower than the sun. In this way, taking Y = 365, we get the sidereal periods of planets given in Table 3. It may be noted that these sidereal periods are heliocentric sidereal periods.

Table 3 Vedic Sidereal periods of planets

Planet	S	S±Y	Sidereal period (years)	Modern value
Mercury	118	483	0.244	0.2417
Venus	587	952	0.616	0.6152
Mars	779	414	1.882	1.881
Jupiter	398	33	12.06	11.862
Saturn	377	12	31.42	29.458

(c) **The moving eccentric circles** : Now after getting the synodic periods the next thing that would have been noticed by the astronomer-priests is that for Mercury and Venus the duration between eastern elongation and western elongation through inferior conjunction is shorter than that between western elongation and eastern elongation through superior conjunction. Similarly in the case of other three planets the duration between western quadrature and eastern quadrature through opposition is shorter than that between eastern quadrature and western quadrature through conjunction. These durations are indicated by the numerator and denominator in Table 2 column 2. In the first place this would have been taken care of by having different speeds of motion in the two sections. However it would have dawned on the minds of astronomer-priests that the planets are not moving in circles with Earth as center but their motion occurs in eccentric circles. And since the phenomena are connected with the Sun the center of these circles ought to coincide with the Sun. Further these circles would revolve around the earth along with the Sun. Thus there is only one circle, viz., the orbit of the Sun around the Earth which carries all other circles that produce the planetary phenomena as well as the phases of the moon. This idea is inherent in the vedic quotation:

sapta yujanti ratham ekacakram eko vahati saptanāmnā

(*Ṛgveda* 164.2.1)

It means 'The one wheel chariot is driven by seven horses, it is one horse which has seven names'.

This model can be used for calculating the elongations of the planets i.e. their angular distance from the Sun.

CONSEQUENCES OF ECCENTRIC MOVING CIRCLE MODEL

(a) **Mercury and Venus** : As these planets are never in opposition to the Sun, the radii of their orbits around the Sun have to be smaller than the radius of the orbit of the Sun around the Earth. In Fig.1, E is the Earth and S the Sun in its circular orbit around the Earth. M_e, M_e and V, V′ are the positions of Mercury and Venus, respectively, at the eastern and western elongation in their respective orbits around the Sun so that E M_e, E M_e, EV, EV′ are tangent to those circles. Such a model was known to Egyptians which is said to be borrowed by the Greeks. It is very likely that it was known in other ancient civilizations of Babylon and India. Now it can be seen that arcs $M_e M_e$ and VV′ towards the Earth (2ϕ) are shorter than those in the opposite direction $2(\pi-\phi)$. They are indicated in days as numerator and denominator in Table 2 and $2\phi/2(\pi-\phi)$ in the first row in Table 4. On converting them into degrees we get the value of 2ϕ and ϕ given in 2nd and 3rd row of Table 4.

Table 4: Radii of planetary orbits

Planets	Mercury	Venus	Mars	Jupiter	Saturn
$\frac{2\phi}{2(\pi-\phi)}$ (d)	$\frac{43}{75}$	$\frac{147}{440}$	$\frac{206}{573}$	$\frac{176}{222}$	$\frac{176}{205}$
2ϕ (degrees)	131	90	95	159	164
ϕ (degrees)	65.5	45.0	47.5	79.5	82
θ (degrees)	24.5	45.0	42.5	10.5	8
'a'	0.414	0.707	1.48	5.49	7.19
Modern value	0.387	0.723	1.53	5.20	9.54
Period (years)	0.246	0.616	1.882	12.06	31.4
Speed/Sun's speed	1.68	1.15	0.79	0.45	0.23
Modern value	1.60	1.17	0.80	0.43	0.32

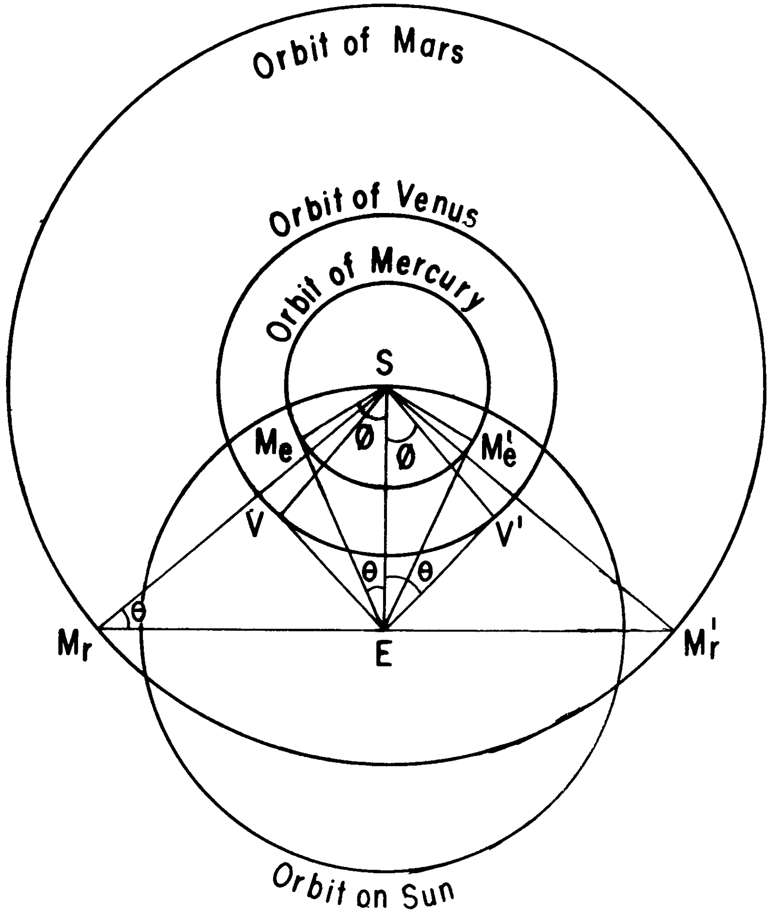

Fig. 1 A model for Mercury, Venus and Mars

Referring to Fig. 1 we find $\theta = 90^{\circ} - \phi$ given in the 4th row. Finally we get the radius of the orbit 'a' in units of radius of the Sun's orbit from $a = \sin\theta$ given in the 5th row. It is true that trignometric functions were not known to the ancients. But from *Śulbasūtras*[8] it is clear that they were familiar with the construction of circles and right angled triangles. So it would have been possible to get 'a' by measurement on a diagram. For example in the case of Venus all they had to do is to draw two right angles triangles SVE and SV′E with angle ϕ at S. Then SV would be the radius perpendicular to EV.

(b) **Mars, Jupiter and Saturn** : In analogy to Venus and Mercury these planets should also move in circular orbits around the sun. But as they show the

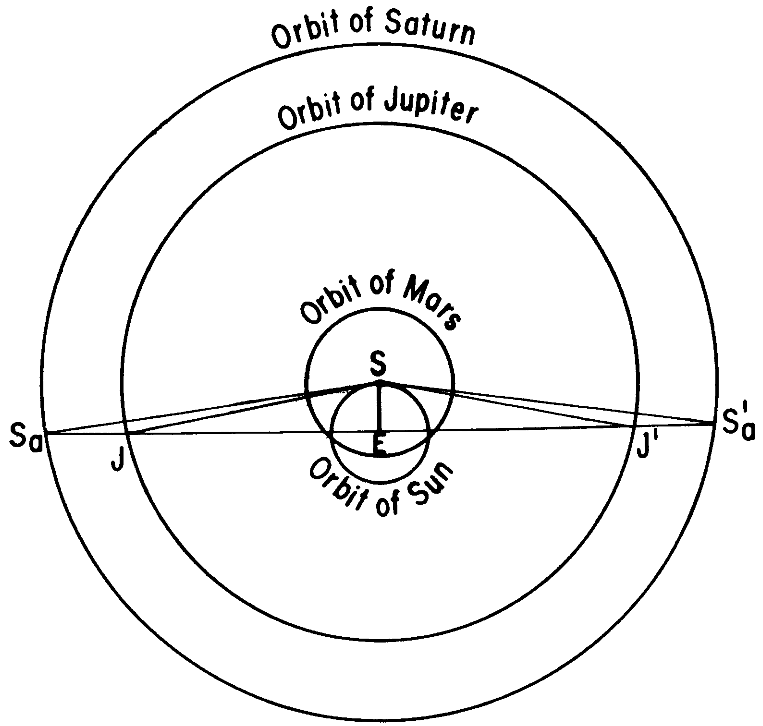

Fig. 2 A model for Mars, Jupiter and Saturn

phenomenon of opposition the radii of their orbits have to be larger than the radius of the Sun's orbit around the earth. In Fig.1, M_r and M_r' represent the position of Mars in its orbit at the times eastern and western quadrature. Here $M_rE_sM_r'$ is perpendicular to SE. Then the angle $M_r SM_r' = 2\phi$ and angle SME $= \theta$; ϕ and θ are also given in Table 4. In this case 'a' = $1/\sin\theta$ as given in Table 4. Similar constructions give the radii of the orbits of Jupiter and Saturn. Fig. 2 shows the orbits of Jupiter and Saturn. The radii and the speeds of planets in their orbits are compared to modern values in Table 4.

(c) Now imagine the Sun moving in a circle around the Earth and the planets orbiting the moving Sun in their respective circular orbits, with the Moon also going round the Earth in its own orbit. In other words we have to rotate Figs. 1 and 2 around the Earth in a period of one year. Then the whole pattern will look like a cobweb entangling the various orbits. This is precisely described in *Rgvedic* quotation:

'*sapta tantunvinvire kavayam ojaso iva*' (*Ṛgveda,* 164.4.2), which means 'the sages have woven seven threads together to form a web'.

(d) **Calculation of Elongation:** In Fig. 3, E is the Earth, S the Sun and P the Planet in its orbit around the Sun. Then the mean anomaly is $\angle ASP = \theta$ where $\theta = \frac{2\pi t}{P\ synodic}$ and $\angle ASP = \varepsilon$, the elongation. So $\angle SPE = \theta - \varepsilon$ which are given by

$\text{Sin}\ \varepsilon/a = \sin\theta/r = \sin(\theta - \varepsilon)/1$, where $r = \sqrt{a^2 + 1 + 2\cos\theta}$.

Therefore $\sin\varepsilon = (a \sin\theta)/r = (a \sin\theta)/\sqrt{a^2 + 1 + 2\cos\theta}$ gives ε if sin and cos functions are known.

When $a > 1$, $r \approx a$ and $\theta - \varepsilon$ is small. So we have

$\theta - \varepsilon = (\sin\theta)/a$

This holds good for Jupiter and Saturn. When $a < 1$, we have maximum ε when $\theta - \varepsilon = 90^\circ$ and $\sin\varepsilon = a$

Most probably Indians knew the sin and cos functions much before the Siddhantic period, because we find methods of calculating sines in all Siddhantic works. If sine functions are not known one can still find ε by measurement on a diagram like Fig. 3.

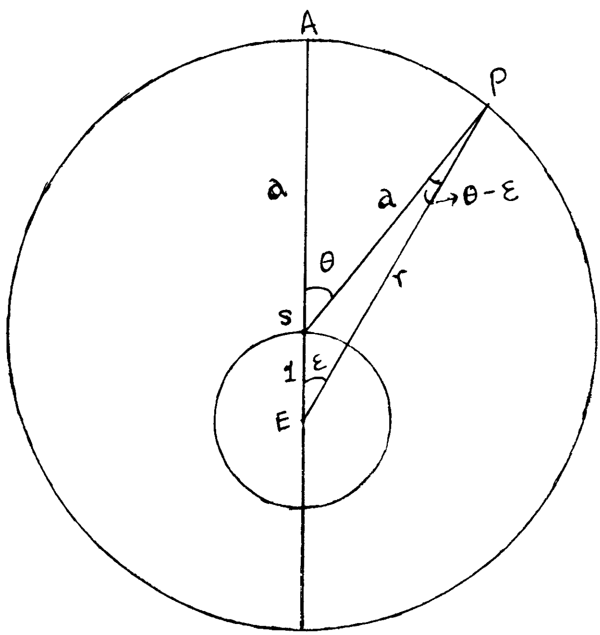

Fig. 3 Calculation of elongation

The difference θ - ε is known as *śighraphala* in siddhantic terminology. There, the speeds of Sun, Moon and Planets are taken to be equal in their orbits so that 'a' is proportional to their sidereal periods. However, for calculating *śighraphala*, 'a' is taken according to their heliocentric values given in Table 4.

Vedic Concept of Cosmos

In the earliest epoch the Vedic universe was considered to have only two parts – *dyaus* (sky) and *pṛthvī* (earth), which were denoted by the duel term *rodasi*. At a later time a third component *antyarikṣa* was introduced as the region between the earth and sky for accommodating the atmospheric phenomena of lightning and the Moon. They were given the names *bhuḥ*(earth), *bhuvaḥ* (*antarikṣa*) and *svaḥ* (sky). When the planetary orbits were known as explained in part 3, the space was divided into seven regions or *lokas* as follows:

(1) *Bhūloka*, the earth, (2) *Bhūvarloka*, *antarikṣa,* (3) *Svarloka*, the region of the Sun, Mercury and Venus, (4) *Mahārloka*, the region of Mars, (5) *Jñaloka*, the region of Jupiter, (6) *Tapaloka*, the region of Saturn, and (7) *Satyaloka*, the region of stars which is known as farthest heaven. Among them the rotating *Bhū* and *Satyam* (the stary globe) were fixed while the others revolved around the Earth, through the Sun.

Discussion

The western historians of astronomy may disagree with the thesis of this paper. According to them [9] all important concepts in the development of astronomy were introduced by the Greeks and Europeans. Egyptians and Babylonians are given credit for a few unripe ideas while the Indians and Chinese are completely left out. However, the Indians had vigourous maritime contacts with the middle east in the 2nd millennium BC as evidenced by excavations at Lothal and Dwaraka, and there was land contact through Baluchistan, Afganistan and Iran which certainly got a fillip after Alexander's expedition in 327 BC. It is also known that students from all over the known world flocked to universities at Taxsila in Punjab and Nalanda in Bihar. So it is not unreasonable to assume that Babylonians, and Greeks like Pythagoras (500 BC) and Euclid (300 BC) may have learnt about the so called Pythagorian theorem through *śulbasūtras*[8] of 800 BC. Ancient Greek historians say that Pythagoras had travelled to the east, but modern western historian dismiss it as a myth. Similarly Appolonius

(203 BC) might have got the idea of moving eccentric circles from India. But he did not center them on the Sun as envisaged in the Indian scheme. He, however, improved upon it by introducing an epicycle for explaining the standstills and retrograde motions of planets.

The idea of epicycle was later applied for explaining the nonuniform motions of the Sun and the Moon by Hipparchus in 170 BC and to planets by Ptolemy in 140 AD. However Indians continued to use mean motions of celestial bodies and developed the idea of Mahāyuga as a common multiple of all periods and the mean helcocentric super conjunction at a remote past epoch.

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7. S. K. Kak (Astronomical code of *Ṛgveda*, Motilal Banarsidas, Delhi, 1994, p. 4) has suggested groupings of Ṛgvedic hymns to match with the synodic periods of planets, and he argued that the coincidence of the suggested grouping of hymns with the synodic periods is statistically highly improbable unless there is a deliberate attempt to have such coincidence. This argument seems reasonable particularly because it is easy for good observers to determine the synodic periods of planets by simple observations over some length of time. It is not necessary to observe their movement among the stars.

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