Archaeoastronomy and literature

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We report the resolution of a long-standing controversy related to the dating of ancient Indian astronomical texts and literature. We show that the Brāhmaṇas, which are post-Vedic texts, cannot be later than the second millennium BC. This means that the chronology of the Indian texts is close to the traditional dates. We sketch the stages of the earliest Indian astronomy.

Astronomers are interested in information related to eclipses, supernovae, and other phenomena in the ancient world. Such phenomena are described in the Indian texts but there has been a long-standing controversy about the chronology of these texts. Although traditional history places the bulk of the Vedic texts in the period of the fourth to the second millennium BC, the chronology proposed by Max Müller[1] and generally adopted in the West dates Rigveda to 1200–1000 BC, the other Vedic texts to 1000–800 BC, and the Brāhmaṇas to 800–600 BC. Influenced by this scheme, Vedāṅga Jyotiṣa, the Vedic manual of astronomy[2], which has an internal date of about 1370 BC, has been ignored by the historians of astronomy, and it has been arbitrarily assigned to a period one thousand years later.

Vedic books do refer to several early astronomical events that take us to various times in the broad period of 4000–2000 BC[3]. For example, there is the well-known statement in the Śatapatha Brāhmaṇa that the *Kṛttikās* (Pleiades) do not swerve from the east which was true of about 2000 BC. Likewise, the earliest nakṣatra lists start with the Kṛttikās and it is generally accepted that these lists count the nakṣatras with the rising on the vernal equinox, but the critics have discounted such evidence arguing that we cannot be certain that the nakṣatras were assigned the same part of the sky as in later Indian astronomy.

In this article we show that it is possible to, unambiguously, date the rites described in the Brāhmaṇas, to the second millennium BC. This means that the Max Müller chronology must now be rejected. For the archaeoastronomer, this allows the placing in context of a vast amount of astronomical information.

The Brāhmaṇas recognize that the speed of the sun varies with the seasons. The year-long rites of the Brāhmaṇas were organized with the summer solstice (*viṣuvant*) as the middle point. There were two years: the ritual one started with the winter solstice (*mahāvrata day*), and the civil one started with the spring equinox (*viṣuva*). Vedic rites had a correspondence with the different stages of the year and, therefore, astronomy played a very significant role in that society. These rites counted the days up to the solstice and in the latter half of the year, and there is an asymmetry in the two counts. This is an astronomical parameter, which had hitherto escaped notice, that allows us to date the rites to no later than the second millennium BC.

Several aspects of the astronomy described in the earliest texts of India have recently become known[4–13]. Most of that material was based on the astronomy of the fire altars. The fire altars are made in a manner so that their areas correspond to the lengths of the lunar or the solar years and as there is a difference between the two types of year, an increase in the area of the fire altar that equals the difference is prescribed in its second construction. Finally, there is a prescription that 95 such altars be built in a sequence defining a 95-year cycle of intercalation.

Recent researches from a variety of fields have led to a new understanding of the chronology of the Vedic literature. Archaeologists and geologists have established that Sarasvatī, the mightiest river of the Rigvedic era which ran down to the sea during that period, is the same as the Ghaggar-Hakra[14]. Since there existed flourishing settlements on the banks of the river prior to about 1900 BC and the fact that we see small settlements on the dry bed which date to the middle of the second millennium BC[15], it is clear that the river dried up around 1900 BC, perhaps due to a major tectonic upheavel. As the Rigvedic hymns speak of Sarasvatī flowing to the sea, the only conclusion open to us is that the Rigvedic era should be considered to be prior to *ca.* 2000 BC. The traditional dating of the Rigveda, considered to belong to an era prior to the Mahābhārata war, is considerably earlier than this period. According to Āryabhaṭa the Mahābhārata war took place *ca.* 3100 BC and according to Varāhamihira it took place *ca.* 2400 BC. It appears that the discrepancy between the two traditions arose due to conflicting interpretations when a calendrical review occurred some time before Āryabhaṭa[8]. On the other hand, according to a French team that surveyed the dried Sarasvatī bed, the river dried up much before 1900 BC and during the Harappan era (2600–1900 BC) the region was irrigated by means of canals[16]. If this were true, then the era of the Rigveda would come even closer to one of the traditional dates. Nevertheless, to be as conservative as possible we take *ca.* 2000 BC as the closing of the Rigvedic age. The astronomy of this era has been described recently[4–11].

The two halves of the year

Aitreya Br. 4.18 describes how the sun reaches the highest point on the day called viṣuvant and how it stays still for a total of 21 days with the viṣuvant being the middle day of this period. In Pañcaviṃśa Br. (chapters 24 and 25), several year-long rites are described where the viṣuvant day is preceded and followed by three-day periods. This suggests that the sun was now taken to be more or less still in the heavens for a total period of 7 days. So it was clearly understood that the shifting of the rising and the setting directions had an irregular motion.

ŚB 4.6.2 describes the rite called *gavām ayana*, the 'sun's walk' or the 'cows' walk'. This is a rite which follows the motion of the sun, with its middle of the viṣuvant day.

Yajurveda (38.20) says that the āhavanīya or the sky altar is four-cornered since the sun is four-cornered, meaning thereby that the motion of the sun is characterized by four cardinal points: the two solstices and the two equinoxes.

The year-long rites list a total of 180 days before the solstice and another 180 days following the solstice. Since this is reckoning by solar days, it is not clearly stated how the remaining 4 or 5 days of the year were assigned. But this can be easily inferred.

Note that the two basic days in this count are the viṣuvant (summer solstice) and the mahāvrata day (winter solstice) which precedes it by 181 days in the above counts. Therefore, even though the count of the latter part of the year stops with an additional 180 days, it is clear that one needs another 4 or 5 days to reach the mahāvrata day in the winter. This establishes that the division of the year was in the two halves of 181 and 184 or 185 days.

Corroboration of this is suggested by evidence related to an altar design from the Śatapatha Brāhmaṇa which is shown in Figure 1. This altar represents the path of the sun around the earth. The middle point, which represents the earth and the atmosphere is at a slight offset to the centre. This fact, and the fact that the number of bricks in the outer ring are not symmetrically placed, shows that the four quarters of the year were not taken to be symmetric.

This inequality would have been easy to discover. The Indians used the reflection of the noon-sun in the water of a deep well to determine the solstice days.

If one assumes that the two halves of the year are directly in proportion to the brick counts of 14 and 15 in the two halves of the ring of the sun, this corresponds to day counts of 176 and 189. This division appears to have been for the two halves of the year with respect to the equinoxes if we note that the solstices divide the year into counts of 181 and 184.

The apparent motion of the sun is the greatest when the earth is at perihelion and the least when the earth is at aphelion. Currently, this speed is greatest in January. The interval between successive perihelia, the anomalistic year, is 365.25964 days which is 0.01845 days longer than the tropical year on which our calendar is based. In 2000 calendar years, the date of the perihelion advances almost 35 days; in 10000 years, it advances almost a half-year (175 days). This means that the perihelion movement has a cycle of about 20000 years.

In the first millennium BC, the earth was at perihelion within the interval prior to the winter solstice. Thus during this period the half of the year from the summer solstice to the winter solstice would have been shorter than the half from the winter solstice to the summer solstice. This is just the opposite of what is described in the rites of the Brāhmaṇas.

It is interesting that the Greeks discovered the asymmetry in the quarters of the year about 400 BC. Modern calculations show that at this time the four quarters of the year starting with the winter solstice were 90.4, 94.1, 92.3, and 88.6 days long. The period from the winter solstice to the summer solstice was then 184.5 days and the perihelion occurred more than a month before the winter solstice[17].

The count of about 181 days from the winter to the summer solstice would be true when the perihelion occurs before the summer solstice. This will require it to move earlier than mid- to late June and no earlier than mid- to late December. In other words, compared to 400 BC, the minimum number of months prior to October is 4 and the maximum number of months is 10. This defines periods which are from 6850 years to 17150 years prior to 400 BC.

These periods appear too early to be considered plausible and this may reflect the fact that the measurements in those times were not very accurate. Nevertheless, it means that the first millennium BC for the rites of the Brāhmaṇas, as has been assumed by colonial historians, is absolutely ruled out.

Since the Śatapatha Br. has lists of teachers that go through more than fifty generations, we know that the period of the Brāhmaṇas was a long one, perhaps a thousand years. To be as conservative as possible, we propose the period 2000–1000 BC as reasonable for these texts. The Vedic Saṃhitās should now be assigned to the earlier fourth and third millennia BC. It is significant that the dating of the second millennium BC is consistent with the recent archaeological findings[18].

Stages of ancient Indian astronomy

Our understanding of the Indian astronomy is undergoing a major shift. More than a hundred years ago, Burgess[19] saw

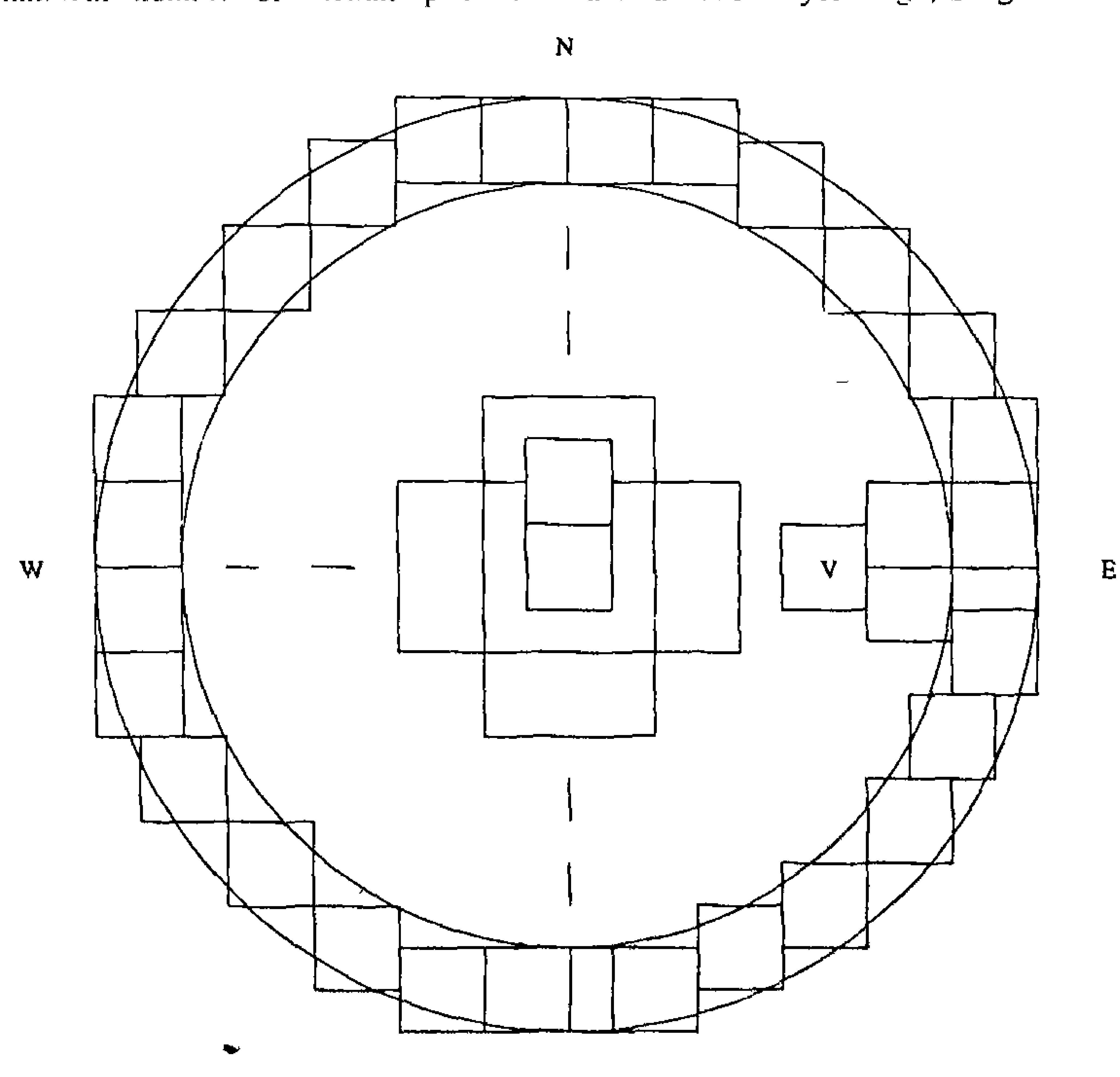

Figure 1. An altar that represents the asymmetric circuit of the sun.

the Indians as the originators of many of the notions that led to the Greek astronomical flowering. This view slowly lost support and then it was believed that Indian astronomy was essentially derivative and it owed all its basic ideas to the Babylonians and the Greeks. It was even claimed that there was no tradition of reliable observational astronomy in India.

Using statistical analysis of the parameters used in the many Siddhāntas, Billard showed[20] that the Siddhāntas were based on precise observations and so the theory of no observational tradition in India was wrong. Since then it has been found that the Vedic books are according to an astronomical plan.

Earlier, it was believed that the mahāyuga/kalpa figure of 4,320,000, which occurs in the Siddhāntas, was borrowed from the astronomy[21] of the Babylonian Berossos (*ca.* 300 BC). But this is already an important astronomical number in the much earlier Śatapatha Brāhmaṇa. The reason why incorrect notions related to Indian astronomy have persisted so long is because the authors have been unfamiliar with a great mass of the literature.

It is also being recognized that the Siddhāntic astronomy has features which are unique to India and it represents an independent tradition. In the words of Thurston[22]:

> Not only did Āryabhaṭa believe that the earth rotates, but there are glimmerings in his system (and other similar Indian systems) of a possible underlying theory in which the earth (and the planets) orbits the sun, rather than the sun orbiting the earth. . . . The significant evidence comes from the inner planets: the period of the śīghrocca is the time taken by the planet to orbit the sun.

It is not clear that Āryabhaṭa was the originator of the idea of the rotation of the earth. It appears that the rotation of the earth is inherent in the notion that the sun never sets that we find in the Aitreya Brāhmaṇa 2.7:

> The [sun] never really sets or rises. In that they think of him 'He is setting,' having reached the end of the day, he inverts himself; thus he makes evening below, day above. Again in that they think of him 'He is rising in the morning,' having reached the end of the night he inverts himself; thus he makes day below, night above. He never sets; indeed he never sets.

One way to visualize it is to see the universe as the hollow of a sphere so that the inversion of the sun now shines the light on the world above ours. But this is impossible since the sun does move across the sky during the day and if the sun does not set or rise it does not move either. Clearly, the idea of 'inversion' denotes nothing but a movement of the earth.

By our study of the early Vedic sources, we are getting into the position of understanding the stages of the development of the earliest astronomy. After the Rigvedic stage comes the period of the Brāhmaṇas. This is followed by Lagadha's astronomy. The last stage is early Siddhāntic and early Purāṇic astronomy.

These four stages are summarized below:

1. *Rigvedic astronomy (ca. 4000–2000 BC).* Motion of the sun and the moon, nakṣatras, planet periods. The start of this stage is a matter of surmise but we have clues such as Vedic myths which have been interpreted to indicate astronomical events of the fourth millennium BC[23].
2. *Astronomy of the Brāhmaṇas (2000–1000 BC).* Astronomy represented by means of geometric altars; non-uniform motion of the sun and the moon; intercalation for the lunar year; 'strings of wind joined to the sun.'
3. *Vedāṅga Jyotiṣa (ca. 1300 BC) [Lagadha].* The text that has come down to us appears to be of a later era[2]. Being the standard manual for determination of the Vedic rites, Lagadha's work must have served as a 'living' text where the language got modified to a later form.
4. *Early Siddhāntic and early Purāṇic (1000 BC–500 AD).* Here our main sources are the Śulbasutras, the Mahābhārata, the early Purāṇas and other texts. Further development of the śīghrocca and mandocca cycles, the concepts of kalpa.

It is significant that these stages are well prior to the rise of mathematical astronomy in Babylonia and in Greece. The concepts of the śīghrocca and mandocca cycles indicate that the motion of the planets was taken to be fundamentally around the sun, which, in turn, was taken to go around the earth.

The mandocca, in the case of the sun and the moon, is the apogee where the angular motion is the slowest and in the case of the other planets it is the aphelion point of the orbit. For the superior planets, the śīghrocca coincides with the mean place of the sun, and in the case of an inferior planet, it is an imaginary point moving around the earth with the same angular velocity as the angular velocity of the planet round the sun; its direction from the earth is always parallel to the line joining the sun and the inferior planet.

The mandocca point serves to slow down the motion from the apogee to the perigee and speed up the motion from the perigee to the apogee. It is a representation of the non-uniform motion of the body, and so it can be seen as a direct development of the idea of the non-uniform motion of the sun and the moon.

The śīghrocca maps the motion of the planet around the sun to the corresponding set of points around the earth. The sun, with its winds that hold the solar system together, is, in turn, taken to go around the earth.

The antecedents of this system can be seen in the earlier texts. ŚB 4.1.5.16 describes the sun as *puṣkaramāditya*, 'the lotus of the sky'. ŚB 8.7.3.10 says:

> The sun strings these worlds [the earth, the planets, the atmosphere] to himself on a thread. This thread is the same as the wind. . .

This suggests a central role to the sun in defining the motions of the planets and ideas such as these must have ultimately led to the theory of the śīghrocca and the mandocca cycles.

Concluding remarks

The theory that the sun was the 'lotus' [the central point] of the sky and that it kept the worlds together by its 'strings of wind' gave rise to the heliocentric tradition in India mentioned by Thurston[18]. The offset of the sun's orbit evolved into the notion of mandocca and the motions of the planets around the sun were transferred to the earth's frame through the device of the śīghrocca.

The continuing analysis of the astronomical references in the Brāhmaṇas has made it clear that the theory that the Siddhāntic astronomy was somehow derived from the Babylonians and the Greeks is wrong. What is emerging from texts, that are anterior, by any reckoning, to the eras of astronomical advance in Babylonia or in Greece is that astronomical ideas developed in India in stages and these stages can be seen in the different layers of the Vedic texts, the Brāhmaṇas, and the Vedāṅga Jyotiṣa.

The evidence from the design of the altar of Figure 1 confirms that the year was divided into two parts: winter solstice to summer solstice being equal to 181 days, and midsummer-to-midwinter of 184 or 185 days. This means that the Brāhmaṇa rites could not belong to the 1st millennium BC. This conclusion is of the greatest significance for the chronology of the Vedic texts and it invalidates the chronology popularized by Max Müller. This work supports the thesis[24] that the Vedic and the Harappan periods were identical.

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Edited and published by Prof. P. Balaram and Prof. S. Ramaseshan, Current Science Association, Bangalore 560 080.
Typeset by R D Typesetters, Bangalore (Ph: 3405672). Printed by Lotus Printers, Bangalore (Ph: 3380167).