Vedic Cosmography and Astronomy

by Richard L. Thompson

The universe as described in the Fifth Canto of *Srimad-Bhagavatam* seems strikingly different from the universe of modern astronomy. This book addresses this apparent conflict in detail, and outlines a systematic approach to understanding the Fifth Canto. Topics include the celestial geometry of Bhu-mandala, mystic powers and higher-dimensional realms, Vedic mathematical astronomy, the dating of Kali-yuga, space travel, the moon flight, astrophysical anomalies, and much more.

The following text is the 1st chapter of this book. Interested readers are directed to purchase the book from the publisher at: http://www.afn.org/~bvi/

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THE ASTRONOMICAL SIDDHĀNTAS

Since the cosmology of the astronomical *siddhāntas* is quite similar to traditional Western cosmology, we will begin our discussion of Vedic astronomy by briefly describing the contents of these works and their status in the Vaiṣṇava tradition. In a number of purports in the *Caitanya-caritāmṛta*, Śrīla Prabhupāda refers to two of the principal works of this school of astronomy, the *Sūrya-siddhānta* and the *Siddhānta-śiromaṇi*. The most important of these references is the following:

> These calculations are given in the authentic astronomy book known as the *Sūrya-siddhānta*. This book was compiled by the great professor of astronomy and mathematics Bimal Prasād Datta,

> later known as Bhaktisiddhānta Sarasvatī Gosvāmī, who was our merciful spiritual master. He was honored with the title Siddhānta Sarasvatī for writing the *Sūrya-siddhānta*, and the title Gosvāmi Mahārāja was added when he accepted *sannyāsa*, the renounced order of life [CC AL 3.8p].

Here the *Sūrya-siddhānta* is clearly endorsed as an authentic astronomical treatise, and it is associated with Śrīla Bhaktisiddhānta Sarasvatī Ṭhākura. The *Sūrya-siddhānta* is an ancient Sanskrit work that, according to the text itself, was spoken by a messenger from the sun-god, Sūrya, to the famous *asura* Maya Dānava at the end of the last Satya-yuga. It was translated into Bengali by Śrīla Bhaktisiddhānta Sarasvatī, who was expert in Vedic astronomy and astrology.
Some insight into Śrīla Bhaktisiddhānta's connection with Vedic astronomy can be found in the bibliography of his writings. There it is stated,

> In 1897 he opened a "Tol" named "Saraswata Chatuspati" in Manicktola Street for teaching Hindu Astronomy nicely calculated independently of Greek and other European astronomical findings and calculations.
> During this time he used to edit two monthly magazines named "Jyotirvid" and "Brihaspati" (1896), and he published several authoritative treatises on Hindu Astronomy.... He was offered a chair in the Calcutta University by Sir Asutosh Mukherjee, which he refused [BS1, pp. 2–3].

These statements indicate that Śrīla Bhaktisiddhānta took considerable interest in Vedic astronomy and astrology during the latter part of the nineteenth century, and they suggest that one of his motives for doing this was to establish that the Vedic astronomical tradition is independent of Greek and European influence. In addition to his Bengali translation of the *Sūrya-siddhānta*, Śrīla Bhaktisiddhānta Sarasvatī published the following works in his two magazines:

> (a) Bengali translation and explanation of *Bhāskarācārya's Siddhānta-Shiromani Goladhyaya* with *Basanabhasya*, (b) Bengali translation of *Ravichandrasayanaspashta*, *Laghujatak*, with

annotation of Bhattotpala, (c) Bengali translation of *Laghuparashariya*, or *Ududaya-Pradip*, with Bhairava Datta's annotation, (d) Whole of *Bhauma-Siddhānta* according to western calculation, (e) Whole of *Ārya-Siddhānta* by Āryabhaṭa, (f) Paramadishwara's *Bhatta Dipika-Tika, Dinakaumudi, Chamatkara-Chintamoni*, and *Jyotish-Tatwa-Samhita* [BS1, p. 26].

This list includes a translation of the *Siddhānta-śiromaṇi*, by the 11th-century astronomer Bhāskarācārya, and the *Ārya-siddhānta*, by the 6th-century astronomer Āryabhaṭa. Bhaṭṭotpala was a well-known astronomical commentator who lived in the 10th century. The other items in this list also deal with astronomy and astrology, but we do not have more information regarding them.

Śrīla Bhaktisiddhānta Sarasvatī also published the *Bhaktibhāvana Pañjikā* and the *Śrī Navadvīpa Pañjikā* (BS2, pp. 56,180). A *pañjikā* is an almanac that includes dates for religious festivals and special days such as Ekādaśī. These dates are traditionally calculated using the rules given in the *jyotiṣa śāstras*.

During the time of his active preaching as head of the Gauḍīya Math, Śrīla Bhaktisiddhānta stopped publishing works dealing specifically with astronomy and astrology. However, as we will note later on, Śrīla Bhaktisiddhānta cites both the *Sūrya-siddhānta* and the *Siddhānta-śiromaṇi* several times in his *Anubhāṣya* commentary on the *Caitanya-caritāmṛta*.

It is clear that in recent centuries the *Sūrya-siddhānta* and similar works have played an important role in Indian culture. They have been regularly used for preparing calendars and for performing astrological calculations. In Section 1.c we cite evidence from the *Bhāgavatam* suggesting that complex astrological and calendrical calculations were also regularly performed in Vedic times. We therefore suggest that similar or identical systems of astronomical calculation must have been known in this period.

Here we should discuss a potential misunderstanding. We have stated that Vaiṣṇavas have traditionally made use of the astronomical *siddhāntas* and that both Śrīla Prabhupāda and Śrīla Bhaktisiddhānta Sarasvatī Ṭhākura have referred to them. At the same time, we have pointed out that the authors of the astronomical *siddhāntas*, such as Bhāskarācārya, have been unable to accept some of the cosmological statements in the *Purāṇas*. How could Vaiṣṇava *ācāryas* accept works which criticize the *Purāṇas*?

We suggest that the astronomical *siddhāntas* have a different status than transcendental literature such as the *Śrīmad-Bhāgavatam*. They are authentic in the sense that they belong to a genuine Vedic astronomical tradition, but they are nonetheless human works that may contain imperfections. Many of these works, such as the *Siddhānta-śiromaṇi*, were composed in recent centuries and make use of empirical observations. Others, such as the *Sūrya-siddhānta*, are attributed to demigods but were transmitted to us by persons who are not spiritually perfect. Thus the *Sūrya-siddhānta* was recorded by Maya Dānava. Śrīla Prabhupāda has said that Maya Dānava "is always materially happy because he is favored by Lord Śiva, but he cannot achieve spiritual happiness at any time" (SB 5.24cs).

The astronomical *siddhāntas* constitute a practical division of Vedic science, and they have been used as such by Vaiṣṇavas throughout history. The thesis of this book is that these works are surviving remnants of an earlier astronomical science that was fully compatible with the cosmology of the *Purāṇas*, and that was disseminated in human society by demigods and great sages. With the progress of Kali-yuga, this astronomical knowledge was largely lost. In recent centuries the knowledge that survived was reworked by various Indian astronomers and brought up to date by means of empirical observations.

Although we do not know anything about the methods of calculation used before the Kali-yuga, they must have had at least the same scope and order of sophistication as the methods presented in the *Sūrya-siddhānta*. Otherwise they could not have produced comparable results.

In presently available Vedic literature, such computational methods are presented only in the astronomical *siddhāntas* and other *jyotiṣa śāstras*. The *Itihāsas* and *Purāṇas* (including the *Bhāgavatam*) do not contain rules for astronomical calculations, and the *Vedās* contain only the *Vedāṅga-jyotiṣa*, which is a *jyotiṣa śāstra* but is very brief and rudimentary (VJ).

The following is a brief summary of the topics covered by the *Sūrya-siddhānta*: (1) computation of the mean and true positions of the planets in the sky, (2) determination of latitude and longitude and local celestial coordinates, (3) prediction of full and partial eclipses of the moon and sun, (4) prediction of conjunctions of planets with stars and other planets, (5) calculation of the rising and setting times of planets and stars, (6) calculation of the moon's phases, (7) calculation of the dates of various astrologically significant planetary combinations (such as Vyatīpāta), (8) a discussion of cosmography, (9) a discussion of astronomical instruments, and (10) a discussion of kinds of time. We will first discuss the computation of mean and true planetary positions, since it introduces the *Sūrya-siddhānta's* basic model of the planets and their motion in space.

1.A. The Solar System According to the Sūrya–siddhānta

The *Sūrya-siddhānta* treats the earth as a globe fixed in space, and it describes the seven traditional planets (the sun, the moon, Mars, Mercury, Jupiter, Venus, and Saturn) as moving in orbits around the earth. It also describes the orbit of the planet Rāhu, but it makes no mention of Uranus, Neptune, and Pluto. The main function of the *Sūrya-siddhānta* is to provide rules allowing us to calculate the positions of these planets at any given time. Given a particular date, expressed in days, hours, and minutes since the beginning of Kali-yuga, one can use these rules to compute the direction in the sky in which each of the seven planets will be found at that time. All of the other calculations described above are based on these fundamental rules.

The basis for these rules of calculation is a quantitative model of how the planets move in space. This model is very similar to the modern Western model of the solar system. In fact, the only major difference between these two models is that the *Sūrya-siddhānta's* is geocentric, whereas the model of the solar system that forms the basis of modern astronomy is heliocentric.

To determine the motion of a planet such as Venus using the modern heliocentric system, one must consider two motions: the motion of Venus around the sun and the motion of the earth around the sun. As a crude first approximation, we can take both of these motions to be circular. We can also imagine that the earth is stationary and that Venus is revolving around the sun, which in turn is revolving around the earth. The relative motions of the earth and Venus are the same, whether we adopt the heliocentric or geocentric point of view.
In the *Sūrya-siddhānta* the motion of Venus is also described, to a first approximation, by a combination of two motions, which we can call cycles 1 and 2. The first motion is in a circle around the earth, and the second is in a circle around a point on the circumference of the first circle. This second circular motion is called an epicycle.

It so happens that the period of revolution for cycle 1 is one earth year, and the period for cycle 2 is one Venusian year, or the time required for Venus to orbit the sun according to the heliocentric model. Also, the sun is located at the point on the circumference of cycle 1 which serves as the center of rotation for cycle 2. Thus we can interpret the *Sūrya-siddhānta* as saying that Venus is revolving around the sun, which in turn is revolving around the earth (see Figure 1). According to this interpretation, the only difference between the *Sūrya-siddhānta* model and the modern heliocentric model is one of relative point of view.

Table 1
Planetary Years, Distances, and Diameters,
According to Modern Western Astronomy

Planet	Length of year	Mean Distance from Sun	Mean Distance from Earth	Diameter
Sun	—	0.	1.00	865,110
Mercury	87.969	.39	1.00	3,100
Venus	224.701	.72	1.00	7,560
Earth	365.257	1.00	0.	7,928
Mars	686.980	1.52	1.52	4,191
Jupiter	4,332.587	5.20	5.20	86,850
Saturn	10,759.202	9.55	9.55	72,000
Uranus	30,685.206	19.2	19.2	30,000
Neptune	60,189.522	30.1	30.1	28,000
Pluto	90,465.38	39.5	39.5	?

Years are equal to the number of earth days required for the planet to revolve once around the sun. Distances are given in astronomical units (AU), and 1 AU is equal to 92.9 million miles, the mean distance from the earth to the sun. Diameters are given in miles. (The years are taken from the standard astronomy text

TSA, and the other figures are taken from EA.)

In Tables 1 and 2 we list some modern Western data concerning the sun, the moon, and the planets, and in Table 3 we list some data on periods of planetary revolution taken from the *Sūrya-siddhānta*. The periods for cycles 1 and 2 are given in revolutions per *divya-yuga*. One *divya-yuga* is 4,320,000 solar years, and a solar year is the time it takes the sun to make one complete circuit through the sky against the background of stars. This is the same as the time it takes the earth to complete one orbit of the sun according to the heliocentric model.

TABLE 2
Data pertaining to the Moon,
According to Modern Western Astronomy

Siderial Period	27.32166 days
Synodic Period	29.53059 days
Nodal Period	27.2122 days
Siderial Period of Nodes	-6,792.28 days
Mean Distance from Earth	238,000 miles = .002567 AU
Diameter	2,160 miles

The sidereal period is the time required for the moon to complete one orbit against the background of stars. The synodic period, or month, is the time from new moon to new moon. The nodal period is the time required for the moon to pass from ascending node back to ascending node. The sidereal period of the nodes is the time for the ascending node to make one revolution with respect to the background of stars. (This is negative since the motion of the nodes is retrograde.) (EA)

For Venus and Mercury, cycle 1 corresponds to the revolution of the earth around the sun, and cycle 2 corresponds to the revolution of the planet around the sun. The times for cycle 1 should therefore be one revolution per solar year, and, indeed, they are listed as 4,320,000 revolutions per *divya-yuga*.

The times for cycle 2 of Venus and Mercury should equal the modern heliocentric years of these planets. According to the *Sūrya-siddhānta*, there are 1,577,917,828 solar days per *divya-yuga*. (A solar day is the time from sunrise to sunrise.) The cycle-2 times can be computed in solar days by dividing this number by the revolutions per *divya-yuga* in cycle 2. The cycle-2 times are listed as "SS [Sūrya-siddhānta] Period," and they are indeed very close to the heliocentric years, which are listed as "W [Western] Period" in Table 3.

For Mars, Jupiter, and Saturn, cycle 1 corresponds to the revolution of the planet around the sun, and cycle 2 corresponds to the revolution of the earth around the sun. Thus we see that cycle 2 for these planets is one solar year (or 4,320,000 revolutions per *divya-yuga*). The times for cycle 1 in solar days can also be computed by dividing the revolutions per *divya-yuga* of cycle 1 into 1,577,917,828, and they are listed under "SS Period." We can again see that they are very close to the corresponding heliocentric years.

For the sun and moon, cycle 2 is not specified. But if we divide 1,577,917,828 by the numbers of revolutions per *divya-yuga* for cycle 1 of the sun and moon, we can calculate the number of solar days in the orbital periods of these planets. Table 3 shows that these figures agree well with the modern values, especially in the case of the moon. (Of course, the orbital period of the sun is simply one solar year.)

TABLE 3
Planetary Periods According to the Sūrya-siddhānta

Planet	Cycle 1	Cycle 2	SS Period	W Period
Moon	57,753,336	*	27.322	27.32166
Mercury	4,320,000	17,937,000	87.97	87.969
Venus	4,320,000	7,022,376	224.7	224.701
Sun	4,320,000	*	365.26	365.257
Mars	2,296,832	4,320,000	687.0	686.980
Jupiter	364,220	4,320,000	4,332.3	4,332.587
Saturn	146,568	4,320,000	10,765.77	10,759.202
Rāhu	-232,238	*	-6,794.40	-6,792.280

The figures for cycles 1 and 2 are in revolutions per *divya-yuga*. The "SS Period" is equal to 1,577,917,828, the number of solar days in a *yuga* cycle, divided by one of the two cycle figures (see the text). This should give the heliocentric period for Mercury, Venus, the earth (under sun) Mars, Jupiter, and Saturn, and it shold give the geocentric period for the moon and Rāhu. These periods can be compared with the years in Table 1 and the sidereal periods of the moon and its nodes in Table 2. These quantities have been reproduced from Tables 1 and 2 in the column labeled "W Period."

In Table 3 a cycle-1 value is also listed for the planet Rāhu. Rāhu is not recognized by modern Western astronomers, but its position in space, as described in the *Sūrya-siddhānta*, does correspond with a quantity that is measured by modern astronomers. This is the ascending node of the moon.

From a geocentric perspective, the orbit of the sun defines one plane passing through the center of the earth, and the orbit of the moon defines another such plane. These two planes are slightly tilted with respect to each other, and thus they intersect on a line. The point where the moon crosses this line going from celestial south to celestial north is called the ascending node of the moon. According to the *Sūrya-siddhānta*, the planet Rāhu is located in the direction of the moon's ascending node.

From Table 3 we can see that the modern figure for the time of one revolution of the moon's ascending node agrees quite well with the time for one revolution of Rāhu. (These times have minus signs because Rāhu orbits in a direction opposite to that of all the other planets.)

TABLE 4

Heliocentric Distances of Planets, According to the Sūrya-siddhānta

Planet	Cycle 1	Cycle 2	SS Distance	W Distance
Mercury	360	133 132	.368	.39
Venus	360	262 260	.725	.72
Mars	360	235 232	1.54	1.52
Jupiter	360	70 72	5.07	5.20
Saturn	360	39 40	9.11	9.55

These are the distances of the planets from the sun. The mean heliocentric distance of Mercury and Venus in AU should be given by its mean cycle-2 circumference divided by its cycle-1 circumference. (The cycle-2 circumferences vary between the indicated limits, and we use their average values.) For the other planets the mean heliocentric distance should be the reciprocal of this (see the text). These figures are listed as "SS Distance," and the corresponding modern Western heliocentric distances are listed under "W Distance."

If cycle 1 for Venus corresponds to the motion of the sun around the earth (or of the earth around the sun), and cycle 2 corresponds to the motion of Venus around the sun, then we should have the following equation:

$$\frac{\text{circumference of cycle 2}}{\text{circumference of cycle 1}} = \frac{\text{Venus-to-Sun distance}}{\text{Earth-to-Sun distance}}$$

Here the ratio of distances equals the ratio of circumferences, since the circumference of a circle is 2 *pi* times its radius. The ratio of distances is equal to the distance from Venus to the sun in astronomical units (AU), or units of the earth-sun distance. The modern values for the distances of the planets from the sun are listed in Table 1. In Table 4, the ratios on the left of our equation are computed for Mercury and Venus, and we can see that they do agree well with the modern distance figures. For Mars, Jupiter, and Saturn, cycles 1 and 2 are switched, and thus we are interested in comparing the heliocentric distances with the reciprocal of the ratio on the left of the equation. These quantities are listed in the table, and they also agree well with the modern values. Thus, we can conclude that the *Sūrya-siddhānta* presents a picture of the relative motions and positions of the planets Mercury, Venus, Earth, Mars, Jupiter, and Saturn that agrees quite well with modern astronomy.

1.B. The Opinion of Western Scholars

This agreement between Vedic and Western astronomy will seem surprising to anyone who is familiar with the cosmology described in the

Fifth Canto of the *Śrīmad-Bhāgavatam* and in the other *Purāṇas*, the *Mahābhārata*, and the *Rāmāyaṇa*. The astronomical *siddhāntas* seem to have much more in common with Western astronomy than they do with Purāṇic cosmology, and they seem to be even more closely related with the astronomy of the Alexandrian Greeks. Indeed, in the opinion of modern Western scholars, the astronomical school of the siddhāntas was imported into India from Greek sources in the early centuries of the Christian era. Since the *siddhāntas* themselves do not acknowledge this, these scholars claim that Indian astronomers, acting out of chauvinism and religious sentiment, Hinduized their borrowed Greek knowledge and claimed it as their own. According to this idea, the cosmology of the *Purāṇas* represents an earlier, indigenous phase in the development of Hindu thought, which is entirely mythological and unscientific.
This, of course, is not the traditional Vaiṣṇava viewpoint. The traditional viewpoint is indicated by our observations regarding the astronomical studies of Śrīla Bhaktisiddhānta Sarasvatī Ṭhākura, who founded a school for "teaching Hindu Astronomy nicely calculated independently of Greek and other European astronomical findings and calculations."

The *Bhāgavatam* commentary of the Vaiṣṇava scholar Vaṁśīdhara also sheds light on the traditional understanding of the *jyotiṣa śāstras*. His commentary appears in the book of *Bhāgavatam* commentaries Śrīla Prabhupāda used when writing his purports. In Appendix 1 we discuss in detail Vaṁśīdhara's commentary on SB 5.20.38. Here we note that Vaṁśīdhara declares the *jyotiṣa śāstra* to be the "eye of the *Vedas*," in accord with verse 1.4 of the *Nārada-saṁhitā*, which says, "The excellent science of astronomy comprising *siddhānta*, *saṁhitā*, and horā as its three branches is the clear eye of the *Vedas*" (BJS, xxvi).

Vaiṣṇava tradition indicates that the *jyotiṣa śāstra* is indigenous to Vedic culture, and this is supported by the fact that the astronomical *siddhāntas* do not acknowledge foreign source material. The modern scholarly view that all important aspects of Indian astronomy were transmitted to India from Greek sources is therefore tantamount to an accusation of fraud. Although scholars of the present day do not generally declare this openly in their published writings, they do declare it by implication, and the accusation was explicitly made by the first British Indologists in the early nineteenth century.

John Bentley was one of these early Indologists, and it has been said of his work that "he thoroughly misapprehended the character of the Hindu astronomical literature, thinking it to be in the main a mass of forgeries framed for the purpose of deceiving the world respecting the antiquity of the Hindu people" (HA, p. 3). Yet the modern scholarly opinion that the *Bhāgavatam* was written after the ninth century A.D. is tantamount to accusing it of being a similar forgery. In fact, we would suggest that the scholarly assessment of Vedic astronomy is part of a general effort on the part of Western scholars to dismiss the Vedic literature as a fraud.

A large book would be needed to properly evaluate all of the claims made by scholars concerning the origins of Indian astronomy. In Appendix 2 we indicate the nature of many of these claims by analyzing three cases in detail. Our observation is that scholarly studies of Indian astronomy tend to be based on imaginary historical reconstructions that fill the void left by an almost total lack of solid historical evidence. Here we will simply make a few brief observations indicating an alternative to the current scholarly view. We suggest that the similarity between the *Sūrya-siddhānta* and the astronomical system of Ptolemy is not due to a one-sided transfer of knowledge from Greece and Alexandrian Egypt to India. Due partly to the great social upheavals following the fall of the Roman Empire, our knowledge of ancient Greek history is extremely fragmentary. However, although history books do not generally acknowledge it, evidence does exist of extensive contact between India and ancient Greece. (For example, see PA, where it is suggested that Pythagoras was a student of Indian philosophy and that *brāhmaṇas* and *yogīs* were active in the ancient Mediterranean world.) We therefore propose the following tentative scenario for the relations between ancient India and ancient Greece: SB 1.12.24p says that the Vedic king Yayāti was the ancestor of the Greeks, and SB 2.4.18p says that the Greeks were once classified among the *kṣatriya* kings of Bhārata but later gave up brahminical culture and became known as *mlecchas*. We therefore propose that the Greeks and the people of India once shared a common culture, which included knowledge of astronomy. Over the course of time, great cultural divergences developed, but many common cultural features remained as a result of shared ancestry and later communication. Due to the vicissitudes of the Kali-yuga, astronomical knowledge may have been lost several times in Greece over the last few thousand years and later regained through communication with India, discovery of old texts, and individual creativity. This brings us down to the late Roman period, in which Greece and India shared similar astronomical systems. The scenario ends with the fall of Rome, the burning of the famous library at Alexandria, and the general destruction of records of the ancient past.

According to this scenario, much creative astronomical work was done by Greek astronomers such as Hipparchus and Ptolemy. However, the origin of many of their ideas is simply unknown, due to a lack of historical records. Many of these ideas may have come from indigenous Vedic astronomy, and many may also have been developed independently in India and the West. Thus we propose that genuine traditions of astronomy existed both in India and the eastern Mediterranean, and that charges of wholesale unacknowledged cultural borrowing are unwarranted.

1.C. The Vedic Calendar and Astrology

In this subsection we will present some evidence from Śrīla Prabhupāda's books suggesting that astronomical computations of the kind presented in the astronomical *siddhāntas* were used in Vedic times. As we have pointed out, many of the existing astronomical *siddhāntas* were written by recent Indian astronomers. But if the Vedic culture indeed dates back thousands of years, as the *Śrīmad-Bhāgavatam* describes, then this evidence suggests that methods of astronomical calculation as sophisticated as those of the astronomical *siddhāntas* were also in use in India thousands of years ago. Consider the following passage from the *Śrīmad-Bhāgavatam*:

> One should perform the *śrāddha* ceremony on the Makara-saṅkrānti or on the Karkaṭa-saṅkrānti. One should also perform this ceremony on the Meṣa-saṅkrānti day and the Tulā-saṅkrānti day, in the *yoga* named Vyatīpāta, on that day in which three lunar *tithis* are conjoined, during an eclipse of either the moon or the sun, on the twelfth lunar day, and in the Śravaṇa-nakṣatra. One should perform this ceremony on the Akṣaya-tṛtīyā day, on the ninth lunar day of the bright fortnight of the month of Kārtika, on the four *aṣṭakās* in the winter season and cool season, on the seventh lunar day of the bright fortnight of the month of Māgha, during the conjunction of Māgha-nakṣatra and the full-moon day, and on the days when the moon is completely full, or not quite completely full, when these days are conjoined with the *nakṣatras* from which the names of certain months are derived. One should also perform the *śrāddha* ceremony on the twelfth lunar day when it is in conjunction with any of the *nakṣatras* named Anurādhā, Śravaṇa, Uttara-phalgunī, Uttarāṣādhā, or Uttara-bhādrapadā. Again, one should perform this ceremony when the eleventh lunar day is in conjunction with either Uttara-phalgunī, Uttarāṣādhā, or Uttara-bhādrapadā. Finally, one should perform this ceremony on days conjoined with one's own birth star [*janma-nakṣatra*] or with Śravaṇa-nakṣatra [SB 7.14.20–23].

This passage indicates that to observe the *śrāddha* ceremony properly one would need the services of an expert astronomer. The *Sūrya-siddhānta* contains rules for performing astronomical calculations of the kind required here, and it is hard to see how these calculations could be performed without some computational system of equal complexity. For example, in the *Sūrya-siddhānta* the Vyatīpāta *yoga* is defined as the time when "the moon and sun are in different *ayanas*, the sum of their longitudes is equal to 6 signs (nearly) and their declinations are equal" (SS, p. 72). One could not even define such a combination of planetary positions without considerable astronomical sophistication.

Similar references to detailed astronomical knowledge are scattered throughout the *Bhāgavatam*. For example, the Vyatīpāta *yoga* is also mentioned in SB 4.12.49–50. And KB p. 693 describes that in Kṛṣṇa's time, people from all over India once gathered at Kurukṣetra on the occasion of a total solar eclipse that had been predicted by astronomical calculation. Also, SB 10.28.7p recounts how Nanda Mahārāja once bathed too early in the Yamunā River—and was thus arrested by an agent of Varuṇa—because the lunar day of Ekādaśī ended at an unusually early hour on that occasion. We hardly ever think of astronomy in our modern day-to-day lives, but it would seem that in Vedic times daily life was constantly regulated in accordance with astronomical considerations.

The role of astrology in Vedic culture provides another line of evidence for the existence of highly developed systems of astronomical calculation in Vedic times. The astronomical *siddhāntas* have been traditionally used in India for astrological calculations, and astrology in its traditional form would be impossible without the aid of highly accurate systems of astronomical computation. Śrīla Prabhupāda has indicated that astrology played an integral role in the *karma-kāṇḍa* functions of Vedic society. A few references indicating the importance of astrology in Vedic society are SB 1.12.12p, 1.12.29p, 1.19.10p, 6.2.26p, 9.18.23p, 9.20.37p, and 10.8.5, and also CC AL 13.89–90 and 17.104.

These passages indicate that the traditions of the Vaiṣṇavas are closely tied in with the astronomical *siddhāntas*. Western scholars will claim that this close association is a product of processes of "Hindu syncretism" that occurred well within the Christian era and were carried out by unscrupulous *brāhmaṇas* who misappropriated Greek astronomical science and also concocted scriptures such as the *Śrīmad-Bhāgavatam*. However, if the Vaiṣṇava tradition is indeed genuine, then this association must be real, and must date back for many thousands of years.

1.D. The Starting Date of Kali–yuga

Imagine the following scene: It is midnight on the meridian of Ujjain in

India on February 18, 3102 B.C. The seven planets, including the sun and moon, cannot be seen since they are all lined up in one direction on the other side of the earth. Directly overhead the dark planet Rāhu hovers invisibly in the blackness of night.

According to the *jyotiṣa śāstras*, this alignment of the planets actually occurred on this date, which marks the beginning of the Kali-yuga. In fact, in the *Sūrya-siddhānta*, time is measured in days since the start of Kali-yuga, and it is assumed that the positions of the seven planets in their two cycles are all aligned with the star Zeta Piscium at day zero. This star, which is known as Revatī in Sanskrit, is used as the zero point for measuring celestial longitudes in the *jyotiṣa śāstras*. The position of Rāhu at day zero is also assumed to be 180 degrees from this star. Nearly identical assumptions are made in other astronomical *siddhāntas*. (In some systems, such as that of Āryabhaṭa, it is assumed that Kali-yuga began at sunrise rather than at midnight. In others, a close alignment of the planets is a_sumed at this time, rather than an exact alignment.)
In the *Caitanya-caritāmṛta* AL 3.9–10, the present date in this day of Brahmā is defined as follows: (1) The present Manu, Vaivasvata, is the seventh, (2) 27 *divya-yugas* of his age have passed, and (3) we are in the Kali-yuga of the 28th *divya-yuga*. The *Sūrya-siddhānta* also contains this information, and its calculations of planetary positions require knowledge of the *ahargana*, or the exact number of elapsed days in Kali-yuga. The Indian astronomer Āryabhaṭa wrote that he was 23 years old when 3,600 years of Kali-yuga had passed (BJS, part 2, p. 55). Since Āryabhaṭa is said to have been born in Śaka 398, or A.D. 476, this is in agreement with the standard *ahargana* used today for the calculations of the *Sūrya-siddhānta*.

For example, October 1, 1965, corresponds to day 1,850,569 in Kali-yuga. On the basis of this information one can calculate that the Kali-yuga began on February 18, 3102 B.C., according to the Gregorian calendar. It is for this reason that Vaiṣṇavas maintain that the pastimes of Kṛṣṇa with the Pāṇḍavas in the battle of Kurukṣetra took place about 5,000 years ago.

Of course, it comes as no surprise that the standard view of Western scholars is that this date for the start of Kali-yuga is fictitious. Indeed, these scholars maintain that the battle of Kurukṣetra itself is fictitious, and that the civilization described in the Vedic literature is simply a product of poetic imagination. It is therefore interesting to ask what modern astronomers have to say about the positions of the planets on February 18, 3102 B.C.

TABLE 5
The Celestial Longitudes of the Planets at the Start of Kali-yuga

Planet	Modern Mean Longitude	Modern True Longitude
Moon	-6;04	-1;14
Sun	-5;40	-3;39
Mercury	-38;09	-19;07
Venus	27;34	8;54
Mars	-17;25	-6;59
Jupiter	11;06	10;13
Saturn	-25;11	-27;52
Rāhu	-162;44	-162;44

This table shows the celestial longitudes of the planets relative to the star Zeta Piscium (Revatī in Sanskrit) at sunrise of February 18, 3102 B.C., the beginning of Kali-yuga. Each longitude is expressed as degrees; minutes.

Table 5 lists the longitudes of the planets relative to the reference star Zeta Piscium at the beginning of Kali-yuga. The figures under "Modern True Longitude" represent the true positions of the planets at this time according to modern calculations. (These calculations were done with computer programs published by Duffett-Smith (DF).) We can see that, according to modern astronomy, an approximate alignment of the planets did occur at the beginning of Kali-yuga. Five of the planets were within 10Ṭ of the Vedic reference star, exceptions being Mercury, at –19Ṭ, and Saturn, at –27Ṭ. Rāhu was also within 18Ṭ of the position opposite Zeta Piscium.

The figures under "Modern Mean Longitude" represent the mean positions of the planets at the beginning of Kali-yuga. The mean position of a planet, according to modern astronomy, is the position the planet would have if it moved uniformly at its average rate of motion. Since the planets speed up and slow down, the true position is sometimes ahead of the mean position and sometimes behind it. Similar concepts of true and mean positions are found in the *Sūrya-siddhānta*, and we note that while the *Sūrya-siddhānta* assumes an exact mean alignment at the start of Kali-yuga, it assumes only an approximate true alignment.
Planetary alignments such as the one in Table 5 are quite rare. To find out how rare they are, we carried out a computer search for alignments by computing the planetary positions at three-day intervals from the start of Kali-yuga to the present. We measured the closeness of an alignment by averaging the absolute values of the planetary longitudes relative to Zeta Piscium. (For Rāhu, of course, we used the absolute value of the longitude relative to a point 180Ṭ from Zeta Piscium.) Our program divided the time from the start of Kali-yuga to the present into approximately 510 ten-year intervals. In this entire period we found only three ten-year intervals in which an alignment occurred that was as close as the one occurring at the beginning of Kali-yuga.
We would suggest that the dating of the start of Kali-yuga at 3102 B.C. is based on actual historical accounts, and that the tradition of an unusual alignment of the planets at this time is also a matter of historical fact.
The opinion of the modern scholars is that the epoch of Kali-yuga was concocted during the early medieval period. According to this

hypothesis, Indian astronomers used borrowed Greek astronomy to determine that a near planetary alignment occurred in 3102 B.C. After performing the laborious calculations needed to discover this, they then invented the fictitious era of Kali-yuga and convinced the entire subcontinent of India that this era had been going on for some three thousand years. Subsequently, many different *Purāṇas* were written in accordance with this chronology, and people all over India became convinced that these works, although unknown to their forefathers, were really thousands of years old.

One might ask why anyone would even think of searching for astronomical alignments over a period of thousands of years into the past and then redefining the history of an entire civilization on the basis of a particular discovered alignment. It seems more plausible to suppose that the story of Kali-yuga is genuine, that the alignment occurring at its start is a matter of historical recollection, and that the *Purāṇas* really were written prior to the beginning of this era.

We should note that many historical records exist in India that make use of dates expressed as years since the beginning of Kali-yuga. In many cases, these dates are substantially less than 3102—that is, they represent times before the beginning of the Christian era. Interesting examples of such dates are given in the book *Ādi Śaṅkara* (AS), edited by S. D. Kulkarni, in connection with the dating of Śaṅkarācārya. One will also find references to such dates in *Age of Bhārata War* (ABW), a series of papers on the date of the M*ahābhārata*, edited by G. C. Agarwala. The existence of many such dates from different parts of India suggests that the Kali era, with its 3102 B.C. starting date, is real and not a concoction of post-Ptolemaic medieval astronomers. (Some references will give 3101 B.C. as the starting date of the Kali-yuga. One reason for this discrepancy is that in some cases a year 0 is counted between A.D. 1 and 1 B.C., and in other cases this is not done.)

At this point the objection might be raised that the alignment determined by modern calculation for the beginning of Kali-yuga is approximate, whereas the astronomical siddhāntas generally assume an exact alignment. This seems to indicate a serious defect in the *jyotiṣa śāstras*.

In reply, we should note that although modern calculations are quite accurate for our own historical period, we know of no astronomical observations that can be used to check them prior to a few hundred years B.C. It is therefore possible that modern calculations are not entirely accurate at 3102 B.C. and that the planetary alignment at that date was nearly exact. Of course, if the alignment was as inexact as Table 5 indicates, then it would be necessary to suppose that a significant error was introduced into the *jyotiṣa śāstras*, perhaps in fairly recent times. However, even this hypothesis is not consistent with the theory that 3102 B.C. was selected by Ptolemaic calculations, since these calculations also indicate that a very rough planetary alignment occurred at this date.

Apart from this, we should note that the astronomical *siddhāntas* do not show perfect accuracy over long periods of time. This is indicated by the *Sūrya-siddhānta* itself in the following statement, which a representative of the sun-god speaks to the *asura* Maya:

> O Maya, hear attentively the excellent knowledge of the science of astronomy which the sun himself formerly taught to the great saints in each of the *yugas*.
> I teach you the same ancient science.... But the difference between the present and the ancient works is caused only by time, on account of the revolution of the *yugas* (SS, p. 2).

According to the *jyotiṣa śāstras* themselves, the astronomical information they contain was based on two sources: (1) revelation from demigods, and (2) human observation. The calculations in the astronomical *siddhāntas* are simple enough to be suitable for hand calculation, but as a result they tend to lose accuracy over time. The above statement by the sun's representative indicates that these works were updated from time to time in order to keep them in agreement with celestial phenomena.

We have made a computer study comparing the *Sūrya-siddhānta* with modern astronomical calculations. This study suggests that the *Sūrya-siddhānta* was probably updated some time around A.D. 1000, since its calculations agree most closely with modern calculations at that time. However, this does not mean that this is the date when the *Sūrya-siddhānta* was first written. Rather, the parameters of planetary motion in the existing text may have been brought up to date at that time. Since the original text was as useful as ever once its parameters were updated, there was no need to change it, and thus it may date back to a very remote period.

A detailed discussion concerning the date and origin of Āryabhaṭa's astronomical system is found in Appendix 2. There we observe that the parameters for this astronomical system were probably determined by observation during Āryabhaṭa's lifetime, in the late 5th and early 6th centuries A.D. Regarding his theoretical methods, Āryabhaṭa wrote, "By the grace of Brahmā the precious sunken jewel of true knowledge has been brought up by me from the ocean of true and false knowledge by means of the boat of my own intellect" (VW, p. 213). This suggests that Āryabhaṭa did not claim to have created anything new. Rather, he simply reclaimed old knowledge that had become confused in the course of time.

In general, we would suggest that revelation of astronomical information by demigods was common in ancient times prior to the beginning of Kali-yuga. In the period of Kali-yuga, human observation has been largely used to keep astronomical systems up to date, and as a result, many parameters in existing works will tend to have a fairly recent origin. Since the Indian astronomical tradition was clearly very conservative and was mainly oriented towards fulfilling customary day-to-day needs, it is quite possible that the methods used in these works are extremely ancient.

As a final point, we should consider the objection that Indian astronomers have not given detailed accounts of how they made observations or how they computed their astronomical parameters on the basis of these observations. This suggests to some that a tradition of

sophisticated astronomical observation never existed in India.
One answer to this objection is that there is abundant evidence for the existence of elaborate programs of astronomical observation in India in recent centuries. The cover of this book depicts an astronomical instrument seen in Benares in 1772 by an Englishman named Robert Barker; it was said to be about 200 years old at that time. About 20 feet high, this structure includes two quadrants, divided into degrees, which were used to measure the position of the sun. It was part of an observatory including several other large stone and brass instruments designed for sighting the stars and planets (PR, pp. 31–33).
Similar instruments were built in Agra and Delhi. The observatory at Delhi was built by Rajah Jayasingh in 1710 under the auspices of Mohammed Shah, and it can still be seen today. Although these observatories are quite recent, there is no reason to suppose that they first began to be built a few centuries ago. It is certainly possible that over a period of thousands of years such observatories were erected in India when needed.

The reason we do not find elaborate accounts of observational methods in the *jyotiṣa śāstras* is that these works were intended simply as brief guides for calculators, not as comprehensive textbooks. Textbooks were never written, since it was believed that knowledge should be disclosed only to qualified disciples. This is shown by the following statement in the *Sūrya-siddhānta*: “O Maya, this science, secret even to the Gods, is not to be given to anybody but the well-examined pupil who has attended one whole year” (SS, p. 56). Similarly, after mention of a motor based on mercury that powers a revolving model of the universe, we find this statement: “The method of constructing the revolving instrument is to be kept a secret, as by diffusion here it will be known to all” (SS, p. 90). The story of the false disciple of Droṇācārya in the *Mahābhārata* shows that this restrictive approach to the dissemination of knowledge was standard in Vedic culture.

1.E. The Distances and Sizes of the Planets

In Section 1.a we derived relative distances between the planets from the orbital data contained in the *Sūrya-siddhānta*. These distances are expressed in units of the earth-sun distance, or AU. In this section we will consider absolute distances measured in miles or *yojanas* and point out an interesting feature of the *Sūrya-siddhānta*: it seems that figures for the diameters of the planets are encoded in a verse in the seventh chapter of this text. These diameters agree quite well with the planetary diameters determined by modern astronomy. This is remarkable, since it is hard to see how one could arrive at these diameters by observation without the aid of powerful modern telescopes.

Absolute distances are given in the *Sūrya-siddhānta* in *yojanas*—the same distance unit used throughout the *Śrīmad-Bhāgavatam*. To convert such a unit into Western units such as miles or kilometers, it is necessary to find some distances that we can measure today and that have also been measured in *yojanas*. Śrīla Prabhupāda has used a figure of eight miles per *yojana* throughout his books, and this information is presumably based on the joint usage of miles and *yojanas* in India. Since some doubt has occasionally been expressed concerning the size of the *yojana*, here is some additional information concerning the definition of this unit of length. One standard definition of a *yojana* is as follows: one *yojana* equals four *krośas*, where a *krośa* is the maximum distance over which a healthy man can shout and be heard by someone with good hearing (AA). It is difficult to pin down this latter figure precisely, but it surely could not be much over two miles. Another definition is that a *yojana* equals 8,000 nṛ, or heights of a man. Using 8 miles per *yojana* and 5,280 feet per mile, we obtain 5.28 feet for the height of a man, which is not unreasonable. In Appendix 1 we give some other definitions of the *yojana* basedon the human body.

A more precise definition of a *yojana* can be obtained by making use of the figures for the diameter of the earth given by Indian astronomers. Āryabhaṭa gives a figure of 1,050 *yojanas* for the diameter of the earth (AA). Using the current figure of 7,928 miles for the diameter of the earth, we obtain 7,928/1,050 = 7.55 miles per *yojana*, which is close to 8. We also note that Alberuni (AL, p. 167) gives a figure of 8 miles per *yojana*, although it is not completely clear whether his mile is the same as ours.

In the *Siddhānta-śiromaṇi* of Bhāskarācārya, the diameter of the earth is given as 1,581 *yojanas* (SSB2, p. 83), and in the *Sūrya-siddhānta* a diameter of 1,600 *yojanas* is used (SS, p. 11). These numbers yield about 5 miles per *yojana*, which is too small to be consistent with either the 8 miles per *yojana* or the 8,000 *nṛ* per *yojana* standards. (At 5 miles per *yojana* we obtain 3.3 feet for the height of a man, which is clearly too short.) The Indian astronomer Parameśvara suggests that these works use another standard for the length of a *yojana*, and this is borne out by the fact that their distance figures are consistently 60% larger than those given by Āryabhaṭa. Thus, it seems clear that a *yojana* has traditionally represented a distance of a few miles, with 5 and approximately 8 being two standard values used by astronomers.
At this point it is worthwhile considering how early Indian astronomers obtained values for the diameter of the earth. The method described in their writings (GP, p. 84) is similar to the one reportedly used by the ancient Greek astronomer Eratosthenes. If the earth is a sphere, then the vertical directions at two different points should differ in angle by an amount equal to 360 times the distance between the points divided by the circumference of the earth. This angle can be determined by measuring the tilt of the noon sunlight from vertical at one place, and simultaneously measuring the same tilt at the other place (assuming that the sun's rays at the two places run parallel to one another). At a separation of, say, 500 miles, the difference in tilt angles should be about 7 degrees, a value that can be easily measured and used to compute the earth's circumference and diameter.

The *Sūrya-siddhānta* lists the diameter of the moon as 480 *yojanas* and the circumference of the moon's orbit as 324,000 *yojanas*. If we convert these figures into miles by multiplying by the *Sūrya-siddhānta* value of 5 miles per *yojana*, we obtain 2,400 and 1,620,000. According to modern Western figures, the diameter of the moon is 2,160 miles, and the circumference of the moon's orbit is 2ṇ times the earth-to-moon distance of 238,000 miles, or 1,495,000 miles. Thus the *Sūrya-siddhānta* agrees closely with modern astronomy as to the size of the moon and its distance from the earth.

TABLE 6
The Diameters of the Planets, According to the Sūrya-siddhānta

Planet	Orbit	Reduced Diameter	SS Yojanas	Diameter Miles	W Diameter Miles	W/SS
Moon	324,000	480.00	480.00	2400.00	2,160.	.90
Sun	4,331,500	486.21	6,500.00	32,500.0	865,110.	26.62
Mercury	4,331,500	45.00	601.60	3,008.0	3,100.	1.03
Venus	4,331,500	60.00	802.13	4,010.6	7,560.	1.89
Earth	0	—	1,600.00	8,000.0	7,928.	.99
Mars	8,146,909	30.00	754.34	3,771.7	4,191.	1.11
Jupiter	51,375,764	52.50	8,324.80	41,624.0	86,850.	2.09
Saturn	127,668,255	37.50	14,776.00	73,882.0	72,000.	.97

The first column lists the planetary orbital circumferences in *yojanas* (SS, p. 87). The second column lists the diameters of the planets in *yojanas* reduced to the orbit of the moon (SS, p, 59). The third column lists the corresponding actual diameters (in *yojanas* and miles). Except for the sun, moon, and earth (where figures are taken from SS, p. 41), these values are computed using the data in columns 1 and 2. The fourth column lists the current Western values for the planetary diameters, and the last column lists the ratios between the Western diameters and the diameters based on the *Sūrya-siddhānta*.

Table 6 lists some figures taken from the *Sūrya-siddhānta* giving the circumferences of the orbits of the planets (with the earth as center), and the diameters of the discs of the planets themselves. The orbital circumferences of the planets other than the moon are much smaller than they should be according to modern astronomy.

The diameter of the moon is also the only planetary diameter that seems, at first glance, to agree with modern data. Thus, the diameter given for the sun is 6,500 *yojanas*, or 32,500 miles, whereas the modern figure for the diameter of the sun is 865,110 miles. The diameter figures for Mercury, Venus, Mars, Jupiter, and Saturn are given in *yojanas* for the size of the planetary disc when projected to the orbit of the moon (see Figure 2). These figures enable us to visualize how large the planets should appear in comparison with the full moon. On the average the figures are too large by a factor of ten, and they imply that we should easily be able to see the discs of the planets with the naked eye. Of course, without the aid of a telescope, we normally see these planets as starlike points.

The discs of the planets Mercury through Saturn actually range from a few seconds of arc to about 1', and for comparison the disc of the full moon covers about 31.2' of arc. This means that a planetary diameter projected to the orbit of the moon should be no greater than 15.4 *yojanas*. From the standpoint of modern thought, it is not surprising that an ancient astronomical work like the *Sūrya-siddhānta* should give inaccurate figures for the sizes of the planetary discs. In fact, it seems remarkable that ancient astronomers lacking telescopes could have seen that the planets other than the sun and moon actually have discs.
If we look more closely at the data in Table 6, however, we can make a very striking discovery. Since the diameters of Mercury through Saturn are projected on the orbit of the moon, their real diameters should be given by the formula:

$$\text{real diameter} = \frac{\text{projected diameter} \times \text{orbital circumference}}{\text{moon's orbital circumference}}$$

If we compute the real diameters using this formula and the data in Table 6, we find that the answers agree very well with the modern figures for the diameters of the planets (see the last three columns of the table). Thus, the distance figures and the values for the projected (or apparent) diameters disagree with modern astronomy, but the actual diameters implied by these figures agree. This is very surprising indeed, considering that modern astronomers have traditionally computed the planetary diameters by using measured values of distances and apparent diameters.

We note that the diameters computed for Mercury, Mars, and Saturn using our formula are very close to the modern values, while the figures for Venus and Jupiter are off by almost exactly 1/2. This is an error, but we suggest that it is not simply due to ignorance of the actual diameters of these two planets. Rather, the erroneous factor of 1/2 may have been introduced when a careless copyist mistook “radius” for “diameter” when copying an old text that was later used in compiling the present *Sūrya-siddhānta*.

This explanation is based on the otherwise excellent agreement that exists between the *Sūrya-siddhānta* diameters and modern values, and on our hypothesis that existing *jyotiṣa śāstras* such as the *Sūrya-siddhānta* may be imperfectly preserved remnants of an older Vedic astronomical science. We suggest that accurate knowledge of planetary diameters existed in Vedic times, but that this knowledge was garbled at some point after the advent of Kali-yuga. However, this knowledge is still present in an encoded form in the present text of the *Sūrya-siddhānta*. The circumferences of the planetary orbits listed in Table 6 are based on the theory of the *Sūrya-siddhānta* that all planets move through space with the same *average* speed. Using this theory, one can compute the average distances of the planets from their average apparent speeds, and this is how the circumferences listed in Table 6 were computed in the *Sūrya-siddhānta*. The same theory concerning the motions of the planets can be found in other works of the siddhāntic school, but it is not mentioned in the *Śrīmad-Bhāgavatam*. This theory disagrees with that of modern astronomers, who maintain that the planets move more slowly the further they are from the sun.

We should emphasize that this theory applies only to the planets' average speeds in circular motion around the earth. The actual speeds of the planets vary in the *Sūrya-siddhānta*, and a rule is given for computing the change in apparent diameter of the planets as their distance from the earth changes. The motions of the planets are said to be caused by the *pravaha* wind and by the action of reins of wind pulled by demigods.

Since the relative distances of the planets derived from the *Sūrya-siddhānta* in Section 1.a are not consistent with the orbital circumferences listed in Table 6, it would seem that the *Sūrya-siddhānta* contains material representing more than one theoretical viewpoint. This also makes sense if we suppose that the surviving *jyotiṣa śāstras* may represent the incompletely understood remnants of a body of knowledge that was more complete in the ancient past.

TABLE 7
Modern Values for Planetary Distances and Diameters vs. Those of the Sūrya-siddhānta

Planet	Mean Distance from Earth	Apparent Diameter	Real Diameter
Moon	agrees	agrees	agrees
Sun	disagrees	agrees	disagrees
Mercury	disagrees	disagrees	agrees
Venus	disagrees	disagrees	off by 1/2
Earth	—	—	agrees
Mars	disagrees	disagrees	agrees
Jupiter	disagrees	disagrees	off by 1/2
Saturn	disagrees	disagrees	agrees

The entry "agrees" means that the Sūrya-siddhānta value falls within about 10% of the modern value. The cases that are "off by 1/2" fall within less than 7% of the modern values after being doubled.

Table 7 sums up our observations on the diameters and distances of the planets given in the *Sūrya-siddhānta*. At present we have no explanation of how diameters agreeing so closely with modern values were found, even though estimates of distances and apparent diameters disagree. According to current astronomical thinking, the real diameters can be obtained only by making measurements using powerful telescopes and then combining these results with accurate knowledge of the planetary distances. However, other methods may have been available in Vedic times.

We should note, by the way, that the numbers for planetary diameters can be found not only in our English translation of the *Sūrya-siddhānta* (SS), but also in Śrīla Bhaktisiddhānta Sarasvatī Ṭhākura's Bengali translation. This strongly indicates that these numbers belong to the original *Sūrya-siddhānta*, and were not inserted as a hoax in recent times.

We should also consider the possibility that the planetary diameters given in the *Sūrya-siddhānta* were derived from Greek sources. It turns out that there is a medieval tradition regarding the distances and diameters of the planets that can be traced back to a book by Ptolemy entitled *Planetary Hypotheses*. In this book the apparent diameters of the planets are given as fractions of the sun's apparent diameter. For the moon, Mercury, Venus, Mars, Jupiter, and Saturn, these apparent diameters are stated by Ptolemy to be, respectively, 1m, nn, nn, nn, nn, and nn (SW, p. 167). Corresponding apparent diameters can be computed from the *Sūrya-siddhānta* data by taking the diameters of the planets reduced to the moon's orbit and dividing by 486.21, the diameter of the sun reduced to the moon's orbit. The values obtained, however, are quite different from Ptolemy's apparent diameters.
Ptolemy also computes actual diameters, expressed as multiples of the earth's diameter, using his apparent diameters and his values for the average distances of the planets from the earth. We have converted his actual diameters into miles by multiplying them by 7,928 miles, our modern value for the diameter of the earth. The results for the moon, Mercury, Venus, Mars, Jupiter, and Saturn are 2,312, 294, 2,246, 9,061, 34,553, and 34,090, respectively. (See SW, p. 170.) Apart from the figure

for the moon, these diameters show no relationship with either the modern planetary diameters or the diameters obtained from the Sūrya-s_ddhānta and listed in Table 6.

The only feature that the *Sūrya-siddhānta* and Ptolemy seem to share with regard to the diameters of the planets is that both give unrealistically large values for apparent diameters. If the planets actually had such large apparent diameters, they would appear to the naked eye as clearly visible discs rather than as stars. The ancient planetary diameters would therefore seem to be completely fictitious, were it not for the fact that in the case of the *Sūrya-siddhānta*, they correspond to realistic, actual diameters as seen from unrealistically short distances.

1.F. The Size of the Universe

In the *Śrīmad-Bhāgavatam* a figure of 500 million *yojanas* is given for the diameter of the universe. On the basis of 8 miles per *yojana*, this comes to 4 billion miles, a distance that can accommodate the orbit of Saturn (according to modern distance figures), but that is smaller than the orbital diameters of Uranus, Neptune, and Pluto. Since this figure for the diameter of the universe seems to be quite small, it is interesting to note the purport given by Śrīla Prabhupāda to CC ML 21.84:

> [Text:] Kṛṣṇa said, "Your particular universe extends four billion miles; therefore it is the smallest of all the universes. Consequently you have only four heads."
> [Purport:] Śrīla Bhaktisiddhānta Sarasvatī Ṭhākura, one of the greatest astrologers of his time, gives information from *Siddhānta-śiromaṇi* that this universe measures 18,712,069,200,000,000 X 8 miles. This is the circumference of this universe. According to some, this is only half the circumference.

In his *Anubhāṣya* commentary on this verse of *Caitanya-caritāmṛta*, Śrīla Bhaktisiddhānta Sarasvatī quotes from *Sūrya-siddhānta* 12.90, "The

circumference of the sphere of the Brahmāndee in which the sun's rays spread is 18,712,080,864,000,000 *yojanas*" (SS, p. 87). Then he quotes *Siddhānta-śiromaṇi*, *Golādhyāya Bhuvana-kośa:* "Some astronomers have asserted the circumference of the circle of heaven to be 18,712,069,200,000,000 *yojanas* in length. Some say that this is the length of the zone binding the two hemispheres of the Brahmāṇḍa. Some Paurāṇikas say that this is the length of the circumference of the Lokāloka Parvata [*adṛśya-dṛśyaka-girim*]Ó (SSB1, p. 126).
Here the circumference of 18,712,069,200,000,000 *yojanas* corresponds to a diameter of 5,956,200,000,000,000 *yojanas*. This number is much larger than the 500,000,000-*yojana* diameter given in the *Bhāgavatam*, and we might ask how it relates to it. According to the *Bhāgavatam* (5.20.37),

> By the supreme will of Kṛṣṇa, the mountain known as Lokāloka has been installed as the outer border of the three worlds—Bhūrloka, Bhuvarloka and Svarloka—to control the rays of the sun throughout the universe. All the luminaries, from the sun up to Dhruvaloka, distribute their rays throughout the three worlds, but only within the boundary formed by this mountain.

This verse reconciles the statement that the 18-quadrillion-*yojana* circumference is the limit of distribution of the sun's rays with the statement that it is the circumference of Lokāloka Mountain. We also note that in SB 5.20.38 the diameter of Lokāloka Mountain is stated to be half the diameter of the universe. This is consistent with the statement in Śrīla Prabhupāda's purport that "according to some, this is only half the circumference." We are thus left with a picture of the universe in which the rays of the sun and other luminaries spread to a radial distance of 2,978,100,000,000,000 *yojanas*, and are there blocked in all directions by an enormous mountain. This mountain lies halfway between the sun and the beginning of the outer coverings of the universe. This means that the distance from the sun to the coverings of the universe is some 5,077 light-years, where a light-year is the distance traveled in one year by a beam of light moving at 186,000 miles per second and we use the *Sūrya-siddhānta*'s 5-mile *yojanas*.

In Chapters 3 and 4 we will say more about the possible relation between this very large universal radius and the much smaller figure given in the *Bhāgavatam*. At present we will consider what the *jyotiṣa śāstras* have to say about the radius of the universe. It turns out that the *Siddhānta-śiromaṇi*, the *Sūrya-siddhānta*, and many other *jyotiṣa śāstras* give a simple rule for computing this number.

The *Sūrya-siddhānta* gives the following rule: "Multiply the number of … revolutions of the moon in a *kalpa* by the moon's orbit…: the product is equal to the orbit of heaven (or the circumference of the middle of the *brahmāṇḍa*): to this orbit the sun's rays reach" (SS, p. 86). If we perform this calculation, we find that the circumference of the *brahmāṇḍa*, or universe, is:

57,753,336 X 1,000 X 324,000 = 18,712,080,864,000,000 *yojanas*

In *The Aryabhatiya* of Aryabhata we find the statement that the circumference of the sky (*ākāśa-kakṣa*) in *yojanas* is equal to 10 times the number of minutes of arc covered by the moon during one *divya-yuga* (AA, p. 13). This comes to:

57,753,336 x 360 x 60 x 10 = 12,474,720,576,000 *yojanas*

When interpreting this figure, we should keep in mind that Āryabhaṭa used a *yojana* of about 7.55 miles rather than 5 miles. If we convert Āryabhaṭa's figure to 5-mile *yojanas*, we obtain a universal circumference that is almost exactly one thousandth of the figure cited in *Sūrya-siddhānta* and *Siddhānta-śiromaṇi*. The reason for this is that Āryabhaṭa used the number of revolutions of the moon in a *divya-yuga* rather than the number of revolutions in a *kalpa*. (There are 1,000 *divya-yugas* per *kalpa*.)
We mention Āryabhaṭa's calculation for the sake of completeness. There are a number of ways in which Āryabhaṭa differs from other Indian astronomers (AA). For example, he is unique in making the four *yugas* equal in length, and he also suggests that the earth rotates daily on its axis. (All other Indian astronomers speak of the *kāla-cakra* rotating around a fixed earth.) Our main point here is that very large figures for the size of the universe were commonly presented in the *jyotiṣa śāstras*, and such figures have been accepted by Śrīla Bhaktisiddhānta Sarasvatī

Ṭhākura and Śrīla Prabhupāda.