

# Babylonian and Indian Astronomy: Early Connections

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## Introduction

Did the Indian and Babylonian astronomy evolve in isolation, was there mutual influence, or was one dependent on the other? Scholars have debated these questions for more than two centuries, and opinion has swung one way or the other with time. The similarities between the two systems that have been investigated are: the use of 30 divisions of the lunar month; the 360 divisions of the civil year; the length of the year; and the solar zodiac. Some have wondered if the Babylonian planetary tables might have played a role in the theories of the siddhāntas.

I shall in this essay go over the essentials of the early Indian and Babylonian astronomy and summarize the latest views on the relationship between them. I shall show that the key ideas found in the Babylonian astronomy of 700 BC are already present in the Vedic texts, which even by the most conservative reckoning are older than that period. I shall also show that the solar zodiac (rāśis) was used in Vedic India and I shall present a plausible derivation of the symbols of the solar zodiac from the deities of the segments.

In view of the attested presence of the Indic people in the Mesopotamian region prior to 700 BC, it is likely that if at all the two astronomies influenced each other, the dependence is of the Babylonian on the Indian. It is of course

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quite possible that the Babylonian innovations emerged independent of the earlier Indic methods.

The Indic presence in West Asia goes back to the second millennium BC in the ruling elites of the Hittites and the Mitanni in Turkey and Syria, and the Kassites in Mesopotamia. The Mitanni were joined in marriage to the Egyptian pharaohs during the second half of the second millennium and they appear to have influenced that region as well.<sup>1</sup> The Ugaritic list 33 gods, just like the count of Vedic gods.

Although the Kassites vanished from the scene by the close of the millennium, Indic groups remained in the general area for centuries, sustaining their culture by links through trade. Thus Sargon defeats one Bagdatti of Uišdiš in 716 BC. The name Bagdatti (Skt. Bhagadatta) is Indic<sup>2</sup> and it cannot be Iranian because of the double 't'.

The Indo-Aryan presence in West Asia persisted until the time of the Persian Kings like Darius and Xerxes. It is attested by the famous *daiva* inscription in which Xerxes (ruled 486-465 BC) proclaims his suppression of the rebellion by the *daiva* worshippers of West Iran.

These Indic groups most likely served as intermediaries for the transmission of ideas of Vedic astronomy to the Babylonians and other groups in West Asia. Since we can clearly see a gap of several centuries in the adoption of certain ideas, one can determine the direction of transmission. The starting point of astronomical studies is the conception of the wheel of time of 360 parts. It permeates Vedic writing and belongs to the 2nd millennium BC or earlier, and we see it used in Babylon only in the second part of first millennium BC.

## Western Histories of Indian Astronomy

The early Western studies of Indian texts duly noted the astronomical references to early epochs going back to three or four thousand BC. As the Indian astronomical texts were studied it was discovered that the Indian methods were different from those used in other civilizations. The French astronomer M. Jean Sylvain Bailly in his classic *Traité de l'Astronomie Indienne et Orientale* (1787) described the methods of the *Sūrya Siddhānta* and other texts and expressed his view that Indian astronomy was very ancient. Struck by the elegance and simplicity of its rules and its archaic features, Bailly be-

lieved that astronomy had originated in India and it was later transmitted to the Chaldeans in Babylon and to the Greeks.

As against this, John Bentley in 1799 in a study in the *Asiatick Researches* suggested that the parameters of the Sūrya Siddhānta were correct for 1091 AD. But Bentley was criticized for failing to notice that the Sūrya Siddhānta had been revised using bīja corrections,<sup>3</sup> and therefore his arguments did not negate the central thesis of Bailly.

Meanwhile, in the next several decades Indian astronomy became a contested subject. Part of the difficulty arose from a misunderstanding of the Indian system due to the unfamiliar structure of its luni-solar system. Later, it became a hostage to the ideas that the Vedic people had come as invaders to India around 1500 BC,<sup>4</sup> and that Indians were otherworldly and uninterested in science and they lacked the tradition of observational astronomy until the medieval times.<sup>5</sup> The inconvenient astronomical dates were brushed aside as untrustworthy. It was argued that astronomical references in the texts either belonged to recent undatable layers or were late interpolations.<sup>6</sup>

As against this, Ebenezer Burgess, the translator of the Sūrya Siddhānta, writing in 1860, maintained that the evidence, although not conclusive, pointed to the Indians being the original inventors or discoverers of:<sup>7</sup> (i) the lunar and solar divisions of the zodiac, (ii) the primitive theory of epicycles, (iii) astrology, and (iv) names of the planets after gods.<sup>8</sup>

With the decipherment of the Babylonian astronomical tablets, it was thought that early Indian astronomy may represent lost Babylonian or Greek inspired systems.<sup>9</sup> But this leads to many difficulties, anticipated more than a hundred years earlier by Burgess, including the *incongruity* of the epochs involved. This only thing that one can do is to lump all the Indian texts that are prior to 500 BC together into a mass of uniform material, as has been proposed by Pingree.<sup>10</sup> But such a theory is considered absurd by Vedic scholars.

The internal date of Vedāṅga Jyotiṣa, a late Vedic text, is about 1300 BC. Although Śaṅkara Bālakṣṇa Dīkṣita's *Bhāratīya Jyotiṣa*,<sup>11</sup> published in the closing years of the 19th century, contained enough arguments against looking for any foreign basis to the Vedāṅga Jyotiṣa, the issue was reopened in the 1960s.<sup>12</sup> The basis behind rearticulation of an already disproven theory was the idea that “the origin of mathematical astronomy in India [is] just one element in a general transmission of Mesopotamian-Iranian cultural forms to northern India during the two centuries that antedated Alexander's conquest

of the Achaemenid empire.”<sup>13</sup>

Overwhelming evidence has since been furnished that disproves this theory,<sup>14</sup> but many people remain confused about the relationship between the two astronomy traditions. The idea that India did not have a tradition of observational astronomy was refuted convincingly by Roger Billard more than thirty years ago. In his book on Indian astronomy,<sup>15</sup> he showed that the parameters used in the various siddhāntas actually belonged to the period at which they were created giving lie to the notion that they were based on some old tables transmitted from Mesopotamia or Greece. The distinguished historian of astronomy B.L. van der Waerden reviewed the ensuing controversy in a 1980 paper titled *Two treatises on Indian astronomy* where he evaluated the views of Billard and his opponent Pingree. He ruled thus:<sup>16</sup>

Billard’s methods are sound, and his results shed new light on the chronology of Indian astronomical treatises and the accuracy of the underlying observations. We have also seen that Pingree’s chronology is wrong in several cases. In one case, his error amounts to 500 years.

For the pre-Siddhāntic period, the discovery of the astronomy of the R̥gveda<sup>17</sup> establishes that the Indians were making careful observations in the Vedic period as well.

One might ask why should one even bother to revisit Pingree’s thesis if it stands discredited. The reason to do so is that it provides a good context to compare Babylonian and Indian astronomy and examine their similarities and differences. It also provides a lesson in how bad method will lead to incongruous conclusions.

It is not my intention to replace Babylon by India as the source of astronomical knowledge. I believe that the idea of development in isolation is simplistic; there existed much interaction between the ancient civilizations. I also believe that the borrowings in the ancient world were at best of the general notions and the details of the astronomical system that arose had features which made each system unique. Rather than assign innovation to any specific group, we can at best speak of specific geographical areas in which, due to a variety of social, economic, and cultural reasons, some new ways of looking at the universe arose. Regarding the problem of astronomy, we cannot ignore the pre-Babylonian Indian literature just as we must not ig-

nore the fact that in the mid-first millennium BC the Babylonians embarked on a notable period of careful astronomical records.<sup>18</sup>

The next section will introduce pre-Vedāṅga Jyotiṣa Indian astronomy which will be followed by an account of Babylonian astronomy so that the question of the relationship between Vedāṅga Jyotiṣa and Babylonian astronomy can be investigated properly. Since the pre-Vedāṅga material belongs mainly to the Saṃhitās that are squarely in the second millennium BC or earlier epochs, it could not have been influenced by Babylonian astronomy. We will also use the evidence from the Brāhmaṇas which also antedate the Babylonian material in the most conservative chronology.

Once we have understood the nature of this earlier astronomy, we will relate it to the Vedāṅga Jyotiṣa and the Babylonian astronomies.

## Pre-Vedāṅga Jyotiṣa Astronomy

Pre-Vedāṅga Jyotiṣa astronomy was described at some length in my essay titled “Astronomy and its role in Vedic culture” in volume 1 of the book<sup>19</sup> where the ritual basis of this science were sketched. It was shown that the organization of the Vedic texts and the altar ritual coded certain astronomical facts about the lunar and solar years. This established that observational astronomy was a part of the tradition during the Vedic period itself. But we will not invoke this knowledge here and restrict ourselves to explicit statements from the Saṃhitās and the Brāhmaṇa literature.

The facts that emerge from the pre-Vedāṅga material include: knowledge of the duration of the year, concept of tithi, naming of ecliptic segments after gods, knowledge of solstices for ritual, the 27- and 12- segment divisions of the ecliptic, and the motions of the sun and the moon.

There were several traditions within the Vedic system. For example, the month was reckoned in one with the new moon, in another with the full moon.

## Nakṣatras

Nakṣatras stand for stars, asterisms or segments of the ecliptic. The moon is conjoined with the 27 nakṣatras on successive nights in its passage around the earth; the actual cycle is of  $27\frac{1}{3}$  days. Because of this extra one-third

day, there is drift in the conjunctions that get corrected in three circuits. Also, the fact that the lunar year is shorter than the solar year by 11+ days implies a further drift through the nakṣatras that is corrected by the use of intercalary months.

The earliest lists of nakṣatras in the Vedic books begin with Kṛttikās, the Pleiades; much later lists dating from sixth century AD begin with Aśvinī when the vernal equinox occurred on the border of Revatī and Aśvinī. Assuming that the beginning of the list marked the same astronomical event, as is supported by other evidence, the earliest lists should belong to the third millennium BC or earlier. Each nakṣatra has a presiding deity (Taittirīya Saṃhitā 4.4.10). In the Vedāṅga Jyotiṣa, the names of the nakṣatra and the deity are used interchangeably. It seems reasonable to assume that such usage had sanction of the tradition.

Table 1 provides a list of the nakṣatras, the presiding deities, and the approximate epoch for the winter and summer solstice for a few selected nakṣatras that are relevant to this paper. It is noteworthy that the earliest Vedic texts provide us statements that recognize the movement of the solstices into new nakṣatras. This provides us a means to find approximate dates for these texts.

The nakṣatras in the Vedāṅga Jyotiṣa represent 27 *equal parts* of the ecliptic. This appears to have been an old tradition since the Saṃhitās (Kāṭhaka and Taittirīya) mention explicitly that Soma is wedded to all the nakṣatras and spends equal time with each. The stars of the nakṣatras are thus just a guide to determine the division of the ecliptic into equal parts. Each nakṣatra corresponds to  $13\frac{1}{3}$  degrees.

The following is a list of the nakṣatras and their locations:

1. **Kṛttikā**, from the root *kṛt*, ‘to cut.’ These are the Pleiades. *Deity*: Agni
2. **Rohiṇī**, ‘ruddy,’ is  $\alpha$  Tauri, Aldebaran. *Deity*: Prajāpati
3. **Mṛgaśīrṣa**, ‘Deer’s head.’ *Deity*: Soma
4. **Ārdrā**, ‘moist,’ is the brilliant star Betelgeuse,  $\alpha$  Orionis. *Deity*: Rudra
5. **Punarvasū**, ‘the two that give wealth again,’ are the stars Castor and Pollux, or  $\alpha$  and  $\beta$  Geminorum. *Deity*: Aditi

6. **Tiṣya**, ‘pleased,’ or **Puṣya**, ‘flowered,’ refers to the age when these stars,  $\alpha, \beta, \gamma, \delta$  Cancrī. *Deity*: Brhaspati
7. **Āśreṣā** or **Āśleṣā**, ‘embracer,’ represents  $\delta, \epsilon, \zeta$  Hydrae. *Deity*: Sarpāḥ
8. **Maghā**, ‘the bounties,’ is the group of stars near Regulus, namely  $\alpha, \eta, \gamma, \zeta, \mu, \epsilon$  Leonis. *Deity*: Pitarah
9. **Pūrvā Phālgunī**, ‘bright,’  $\delta$  and  $\theta$  Leonis. *Deity*: Aryaman (Bhaga)
10. **Uttarā Phālgunī**, ‘bright,’  $\beta$  and 93 Leonis. *Deity*: Bhaga (Aryaman)
11. **Hasta**, ‘hand.’ The stars  $\delta, \gamma, \epsilon, \alpha, \beta$  in Corvus. *Deity*: Savitar
12. **Citrā**, ‘bright.’ This is Spica or  $\alpha$  Virginis. *Deity*: Indra (Tvaṣṭṛ)
13. **Svātī**, ‘self-bound,’ or **Niṣṭyā**, is the Arcturus or  $\alpha$  Bootis. *Deity*: Vāyu
14. **Viśākhā**, ‘without branches.’ The stars  $\alpha, \beta, \sigma$  Librae. *Deity*: Indrāgni
15. **Anurādhā**, ‘propitious,’ ‘what follows Rādhā.’ These are the  $\beta, \delta, \pi$  Scorpii. *Deity*: Mitra
16. **Rohiṇī**, ‘ruddy,’ or **Jyeṣṭhā**, ‘eldest.’ This is Antares,  $\alpha$  Scorpii. *Deity*: Indra (Varuṇa)
17. **Vicṛtau**, ‘the two releasers,’ or **Mūla**, ‘root.’ These are the stars from  $\epsilon$  to  $\lambda, \nu$  Scorpii. *Deity*: Pitarah (Nirṛti)
18. **Pūrvā Āṣādhā**, ‘unconquered,’  $\delta, \epsilon$  Sagittarii. *Deity*: Āpaḥ
19. **Uttarā Āṣādhā**, ‘unconquered,’  $\sigma, \zeta$  Sagittarii. *Deity*: Viśve devaḥ  
**Abhijit**, ‘reaching victory.’ The name refers to a satisfactory completion of the system of nakṣatras. The star is Vega, the brilliant  $\alpha$  Lyrae. This is the star that does not occur in the lists which have only 27 nakṣatras on it. *Deity*: Brahmā
20. **Śroṇā**, ‘lame,’ or **Śravaṇa**, ‘ear.’ This represents Altair,  $\alpha$  Aquillae, with  $\beta$  below it and  $\gamma$  above it. *Deity*: Viṣṇu

21. **Śraviṣṭhā**, ‘most famous.’ It is the diamond-shaped group  $\alpha$ ,  $\beta$ ,  $\delta$ ,  $\gamma$  Delphini. It was later called **Dhaniṣṭhā**, ‘most wealthy.’ *Deity*: Vasavaḥ
22. **Śatabhiṣaj**, ‘having a hundred physicians’ is  $\lambda$  Aquarii and the stars around it. *Deity*: Indra (Varuṇa)
23. **Proṣṭhapadā**, ‘feet of stool,’ are the  $\alpha, \beta$  Pegasi. *Deity*: Aja Ekapād
24. **Uttare Proṣṭhapadā**, ‘feet of stool,’ and later **Bhadrapadā**, ‘auspicious feet.’ These are  $\gamma$  Pegasi and  $\alpha$  Andromedae. *Deity*: Ahir-budhnya
25. **Revatī**, ‘wealthy,’  $\eta, \alpha$  Piscium. *Deity*: Pūṣan
26. **Aśvayujau**, ‘the two horse-harnessers,’ are the stars  $\beta$  and  $\alpha$  Arietis. **Aśvinī** is a later name. *Deity*: Aśvinau
27. **Apabharanī**, ‘the bearers,’ are the 35, 39, 41 Arietis. *Deity*: Yama

The antiquity of the nakṣatra system becomes clear when it is recognized that all the deity names occur in RV 5.51 (this insight is due to Narahari Achar<sup>20</sup>). This hymn by Svastyātreya Ātreya lists the deity names as:

Aśvin, Bhaga, Aditi, Pūṣan, Vāyu, Soma, Bṛhaspati, SARVAGANAḤ,  
Viśve Devaḥ, Agni, Rudra, Mitra, Varuṇa, Indrāgni.

The sarvagaṇaḥ are the gaṇaḥ (groups) such as the Vasavaḥ, Pitarāḥ, Sarpāḥ (including Ahi and Aja), Āpaḥ, and the Ādityagaṇaḥ (Dakṣa Prajāpati, Aryaman, Viṣṇu, Yama, Indra) complete the list. There is no doubt that the ecliptic is meant because the last verse of the hymn refers explicitly to the fidelity with which the sun and the moon move on their path, the ecliptic.

The division of the circle into 360 parts or 720 parts was also viewed from the point of view the nakṣatras by assigning 27 upanakṣatras to each nakṣatra (Śatapatha Br. 10.5.4.5). This constituted an excellent approximation because  $27 \times 27 = 729$ . In other words, imagining each nakṣatra to be further divided into 27 equal parts made it possible to conceptualize half a degree when examining the sky.



Table 1: Nakṣatras with their Deity names and the approximate epoch of winter solstice and spring equinox at the midpoint of each segment

<i>Num</i>	<i>Nakṣatra</i>	<i>Deity</i>	<i>W. Solstice</i>	<i>S. Equinox</i>
1	Kṛttikā	Agni		2000 BC
2	Rohiṇī	Prajāpati		3000 BC
3	Mṛgaśīrṣa	Soma		4000 BC
4	Ārdrā	Rudra		5000 BC
5	Punarvasū	Aditi		6000 BC
6	Tiṣya or Puṣya	Bṛhaspati		
7	Āśreṣā or Āśleṣā	Sarpāḥ		
8	Maghā	Pitarah		
9	Pūrvā Phālgunī	Aryaman		
10	Uttarā Phālgunī	Bhaga		
11	Hasta	Savitar		
12	Citrā	Indra		
13	Svātī or Niṣṭyā	Vāyu		
14	Viśākhā	Indrāgni		
15	Anurādhā	Mitra		
16	Rohiṇī	Indra		
17	Vicṛtau or Mūla	Pitarah	2000 AD	
18	Pūrvā Āṣādhā	Āpaḥ	1000 AD	
19	Uttarā Āṣādhā	Viśve devaḥ	0 AD	
*	Abhijit	Brahmā		
20	Śroṇā or Śravaṇa	Viṣṇu	1000 BC	
21	Śraviṣṭhā or Dhaniṣṭhā	Vasavaḥ	2000 BC	
22	Śatabhiṣaj	Indra	3000 BC	
23	Proṣṭhapadā	Aja Ekapād	4000 BC	
24	Uttare Proṣṭhapadā	Ahirbudhnya	5000 BC	2000 AD
25	Revatī	Pūṣan	6000 BC	1000 AD
26	Aśvayujau	Aśvinau	7000 BC	0 AD
27	Apabharanī	Yama		1000 BC

Abhijit, which comes between the nineteenth and the twentieth in the above list, does not occur in the list of the 27 in Taittirīya Saṃhitā or in Vedāṅga Jyotiṣa. Maitrāyāṇī and Kāṭhaka Saṃhitās and Atharvaveda contain lists with the 28 nakṣatras.

When the asterisms Kṛttikā and Viśākhā defined the spring and the autumn equinoxes, the asterisms Maghā and Śraviṣṭhā defined the summer and the winter solstices.

## The Year and Solstices

There were two kinds of year in use. In one, the year was measured from one winter solstice to another; in the other, it was measured from one vernal equinox to another. Obviously, these years were solar and related to the seasons (tropical).

The wheel of time was defined to have a period of 360 parts. This number seems to have been chosen as the average of 354 days of the lunar year and the 366 days for the solar year.

In TS 6.5.3, it is said that the sun travels moves northward for six months and southward for six months. The Brāhmaṇas speak of ritual that follows the course of the year starting with the winter solstice. For example, the Pañcaviṃśa Brāhmaṇa describes sattras of periods of several days, as well as one year (PB 25.1), 12 years, 1000 days, and 100 years. In these types of ritual the number of days were recorded, providing a means of determining an accurate size of the solar year. The sattrā of 100 years appears to refer to the centennial system of the Saptarṣi calendar.

The solstice day was probably determined by the noon-shadow of a vertical pole. The Aitareya Brahmana speaks of the sun remaining stationary for about 21 days at its furthest point in the north (summer solstice) and likewise for its furthest point in the south (winter solstice). This indicates that the motion of the sun was not taken to be uniform all the time.

## Months

The year was divided into 12 months which were defined with respect to the nakṣatras, and with respect to the movements of the moon.

The Taittirīya Saṃhitā (TS) (4.4.11) gives a list of solar months:

Madhu, Mādhava (Vasanta, Spring), Śukra, Śuci (Grīṣma, Summer), Nabha, Nabhasya (Varṣā, Rains), Iṣa and Ūrja (Śarad, autumn), Sahas and Sahasya (Hemanta, Winter), and Tapa and Tapasya (Śiśir, Deep Winter).

The listing of months by the season implies that parts of the ecliptic were associated with these 12 months. These months are also known by their Āditya names (Table 2). These names vary from text to text, therefore, we are speaking of more than one tradition. It should be noted that different lists of names need not mean usage at different times.

*Table 2:* The twelve months with the nakṣatra named after and Ādityas names (from Viṣṇu Purāṇa)

<i>Month</i>	<i>Nakṣatra</i>	<i>Aditya</i>
Caitra	Citrā	Viṣṇu
Vaiśākha	Viśākhā	Aryaman
Jyaiṣṭha	Jyeṣṭhā	Vivasvant
Āśāḍha	Āśāḍhās	Aṃśu
Śrāvaṇa	Śroṇa	Parjanya
Bhādrapada	Proṣṭhapadas	Varuṇa
Āsvayuja	Aśvinī	Indra
Kārtika	Kṛttikā	Dhātṛ
Mārgaśīrṣa	Mṛgaśīras	Mitra
Pauṣa	Tiṣya	Pūṣan
Māgha	Maghā	Bhaga
Phālguna	Phālgunī	Tvaṣṭā

Now we investigate if the rāśi names associated with the segments were a part of the Vedic tradition or if they were adopted later. In any adoption from Babylonia or Greece, one would not expect a fundamental continuity with the nakṣatra system. Taking the clue from the Vedāṅga Jyotiṣa, where the names of the nakṣatras and the deities are used interchangeably, we will investigate if the rāśi names are associated with the segment deities.

The nakṣatra names of the months each cover  $30^\circ$  of the arc, as against the  $13\frac{1}{3}^\circ$  of the lunar nakṣatra segment. Therefore, the extension of each

month may stretch over upto three nakṣatras with corresponding deities. This will be seen in Figure 1 or in the list below. The choice made in Figure 1, where Vaiśākha begins with the the sun in the ending segment of Āśvinī and the moon at the mid-point of Svātī is the most likely assignment as it bunches the Āśāḍhās and the Phālgunīs in the right months, with the Proṣṭhapadās three-fourths correct and Śroṇā half-correct. The full-moon day of the lunar month will thus fall into the correct nakṣatra. Since the solar and the lunar months are not in synchrony, the mapping would tend to slip upto two nakṣatra signs until it is corrected by the use of the intercalary month. At worst, we get a sequence of rāśis which is out of step by one.

Vaiśākha = Svātī to Anurādhā = Vāyu, Indrāgni, Mitra  
 = Vṛṣa, Bull for Indra, e.g. RV 8.33; also Vāyu is sometimes identified with Indra and the two together called Indravāyū, and Vāyu is also associated with cow (RV 1.134)

Jyaiṣṭha = Anurādhā to Mūla = Mitra, Varuṇa, Pitarah  
 = Mithuna, Gemini, from the cosmic embrace of Mitra and Varuṇa

Āśāḍha = Pūrva Āśāḍhā to Śroṇa = Āpaḥ, Viśve Devaḥ, Viṣṇu  
 = Karka, circle or Cancer, the sign of Viṣṇu's cakṛa (e.g. RV 1.155.6)

Śrāvaṇa = Śroṇa to Śatabhiṣaj = Viṣṇu, Vasavaḥ, Indra  
 = Siṃha, Lion, after Indra as in RV 4.16.14

Bhādrapada = Śatabhiṣaj to U. Proṣṭhapada = Indra, Aja Ekapāda, Ahirbudhnya  
 = Kanyā, Virgin, apparently from Aryaman in the opposite side of the zodiac who is the wooer of maidens, kanyā (RV 5.3.2)

Āśvina = U. Proṣṭhapada to Āśvayujau = Ahirbudhnya, Pūṣan, Āśvayujau  
 = Tulā, Libra, from the Āśvins who denote balance of pairs (e.g.

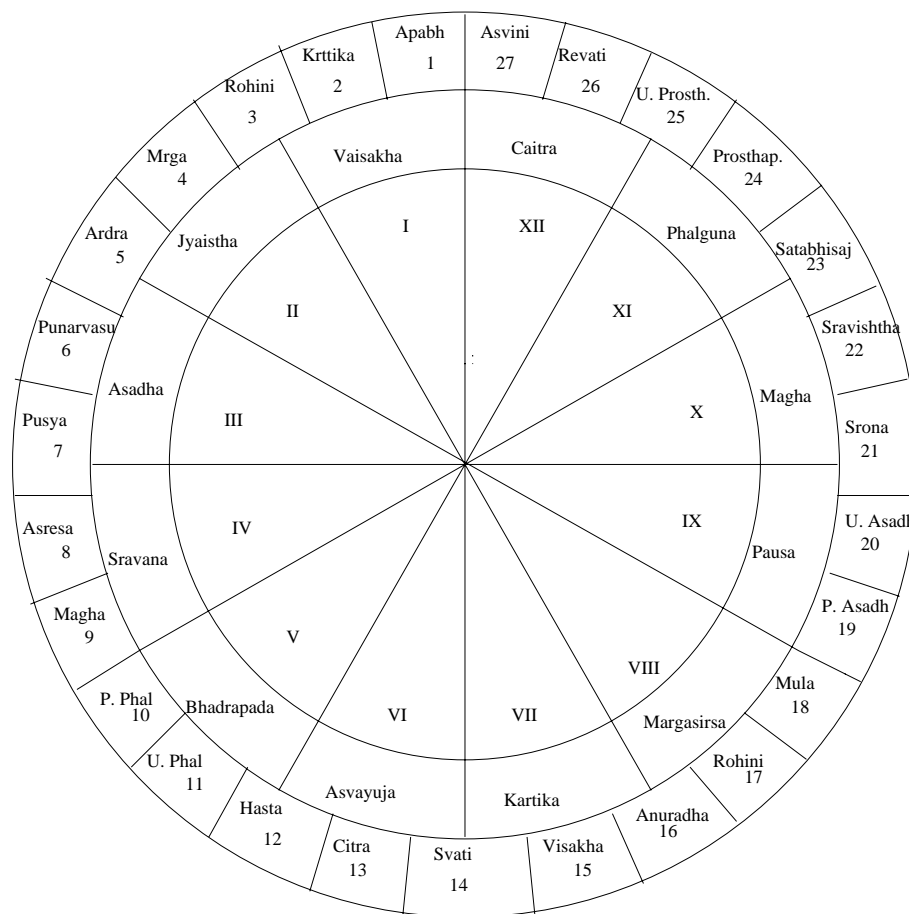


Figure 1: The 27-fold and 12-fold division of the ecliptic. The first rāśi is Vṛṣa with the corresponding month of Vaiśākha

RV 2.39, 5.78, 8.35)

Kārtika = Apabharaṇī to Rohiṇī = Yama, Agni, Prajāpati  
= Ali (Vṛścika), Scorpion, from Kṛttika, to cut

Mārgaśīrṣa = Rohiṇī to Ārdrā = Prajāpati, Soma, Rudra  
= Dhanuṣ, Archer, from the cosmic archer Rudra (RV 2.33, 5.42, 10.125)

Pauṣa = Ārdrā to Puṣya = Rudra, Aditi, Bṛhaspati  
= Makara, Goat, Rudra placing goat-head on Prajāpati, and goat  
is the main animal sacrificed at the ritual of which Bṛhaspati is  
the priest

Māgha = Puṣya to Maghā = Bṛhaspati, Sarpah, Pitarah  
= Kumbha, Water-bearer, from the water-pot offerings to the  
pitarah

Phālguna = Phālgunīs to Hastā = Aryaman, Bhaga, Savitar  
= Mīna, Fish, representing Bhaga (alluded to in RV 10.68)

Caitra = Hastā to Svātī = Savitar, Indra, Vāyu  
= Meṣa, Ram, from Indra, see, e.g., RV 1.51

We observe that for most solar zodiac segments a plausible name emerges from the name of the deity. The choice of the symbols was also governed by another constraint. The Brāhmaṇa texts call the year as the sacrifice and associate different animals with it.<sup>21</sup> In the short sequence, these animals are goat, sheep, bull, horse, and man. Beginning with the goat-dragon at number 9 in the sequence starting with Vaiśākha, we have sheep at 12, bull at 1, horse (also another name for the sun in India) as the sun-disk at 3, and man as archer at 8.

## Intercalation

A system of intercalation of months (adhikamāsa) was used to bring the lunar year in synchrony with the solar year over a period of five years.

The use of the intercalary month (adhikamāsa) goes back to the Ṛgveda itself:

*vedamāso dhṛtavrato dvādaśa prajāvataḥ  
vedā ya upajāyate* (RV 1.25.8)

Dhṛtavrata (Varuṇa) knew the twelve productive months; he also knew about the thirteenth additional month.

In the Atharvaveda (13.3.8), it is said:

*ahorātraivimitaṃ triṃśadaṅgaṃ  
trayodaśaṃ māsam yo nirmimīte* (AV 13.3.8)

He who forms the thirteenth month containing thirty days and nights.

The names of the two intercalary months are given as *saṃsarpa* and *aṃhaspati* in the Taittirīya Saṃhitā 1.4.14.

There are several other similar references in the Saṃhitā literature to the various intercalary schemes that were used to reconcile the lunar and solar years.

## The concept of yuga

The Ṛgveda mentions yuga in what is most likely a five-year sense in RV 1.158.6. The names of two of these five years, *saṃvatsara* and *parivatsara* are to be found in RV 7.103.7. The Vājasaneyi Saṃhitā (27.45 and 30.16) and the Taittirīya Saṃhitā (5.5.7.1-3) give the names of all the five years. These names are: *saṃvatsara*, *parivatsara*, *idāvatvara*, *iduvatsara*, and *vatsara*.

The number five is fundamental to Vedic imagination. Thus there are five-layers of the altar, five breaths within man, five seasons, and five kinds of sacrifices. It was natural then to conceive of a five-year yuga as a basic period since larger yugas were known.

The use of the five year yuga is natural to do a basic synchronization of the lunar and the solar years. Longer periods are required for a more precise synchronization rules.

### Circle of 360°

In R̥gveda 1.164.11, mention is made of the 720 paired sons of the wheel of time which has twelve spokes. These 720 pairs are the 720 days and nights of the civil year. In RV 1.164.48 we are explicitly told of the 360 parts of the wheel of time.

*dvādaśa pradhayaś cakram ekaṃ  
trīṇi nabhyāni ka utacciketa  
tasmin sākaṃ triśatā na śaṅkavo  
arpitāḥ ṣaṣṭirna calācalāsaḥ* (RV 1.164.48)

Twelve spokes, one wheel, three navels, who can comprehend this? In this there are 360 spokes put in like pegs which do not get loosened.

This means that the ecliptic, which is the wheel of time, is divided into 360 parts. Each of these parts is what is now known as a degree. The three navels appear to be the three different kinds of divisions of it: solar and lunar segments and days.

The division of the circle into four quadrants of 90 degrees each is described in another hymn:

*caturbhiḥ sākṃ navatiṃ ca nāmabhiś cakram na vṛttaṃ vyatīḍr  
avīvipat* (RV 1.155.6)

He, like a rounded wheel, hath in swift motion set his ninety racing steeds together with the four.

The division of the wheel of time into 360 parts occurs elsewhere as well. In Śatapatha Br. 10.5.4.4, it is stated that “360 regions encircle the sun on all sides.”

The division into half a degree is very easy to identify in the sky. The radial size of the sun or moon is slightly more than this angular size, being exactly 60/113 degrees.<sup>22</sup>



## Various Divisions of the Ecliptic

One may argue that because the original list of 27 nakṣatras contains only 24 distinct names, these represent the 24 half months of the year. Later, to incorporate lunar conjunctions, the segments were expanded to describe the motions of the moon.

In the Ṛgveda (2.27), six Ādityas are listed which appear to be segments corresponding to the six seasons. The names given are: Mitra, Aryaman, Bhaga, Varuṇa, Dakṣa, Aṁśa.

This notion is supported by the fact that the ecliptic is also described in terms of the twelve Ādityas as in Table 3. In the Śatapatha Brāhmaṇa (6.1.2.8), Prajāpati is said to have “created the twelve Ādityas, and placed them in the sky.” In Śatapatha Br. (11.6.3.8), it is stated that the Ādityas are the twelve months (*dvādaśa māsaḥ*). This means clearly a twelve part division of the circuit of the sun.

The correspondence between the 27-fold division and the 12-fold division of the ecliptic may be seen in Figure 1.

Further division of the ecliptic is seen in the subdivision of each of the rāśis into 2, 3, 4, 7, 9, 10, 12, 16, 20, 24, 27, 30, 40, 45, and 60 parts.

## Nakṣatras and chronology

The list beginning with Kṛttikā at the vernal equinox indicates that it was drawn up in the third millennium BC. The legend of the decapitation of Prajāpati indicates a time when the year began with Mṛgaśīrṣa in the fifth millennium BC (Table 1). Scholars have also argued that a subsequent list began with Rohiṇī. This reasoning is supported by the fact that there are two Rohiṇīs, separated by fourteen nakṣatras, indicating that the two marked the beginning of the two half-years.

In addition to the chronological implications of the changes in the beginning of the Nakṣatra lists, there are other references which indicate epochs that bring us down to the Common Era.

The moon rises at the time of sunset on pūrṇimā, the full moon day. It rises about 50 minutes every night and at the end of the Śivarātri of the month, about two days before amāvasyā, it rises about an hour before sunrise. The crescent moon appears first above the horizon, followed by the rising sun. This looks like the sun as Śiva with the crescent moon adorning

his head. This is the last appearance of the moon in the month before its reappearance on śukla dvitīya. These two days were likely used to determine the day of amāvāsyā.

Mahāśivarātri is the longest night of the year at the winter solstice. At present, this occurs on February  $26 \pm 15$  days (this uncertainty arises from the manner in which the intercalary month operates), and when it was introduced (assuming a calendar similar to the present one), the epoch would have been December  $22 \pm 15$  days. The difference of 66 days gives an epoch of 2600 BC  $\pm$  1100 years for the establishment of this festival.<sup>23</sup>

The Kauṣītaki Br. (19.3) mentions the occurrence of the winter solstice in the new moon of Māgha (*māghasyāmāvāsyāyām*). This corresponds to a range of 1800—900 BC based on the uncertainty related to the precise identification of the Maghā nakṣatra at that time.

The Śatapatha Brāhmaṇa (2.1.2.3) has a statement that points to an earlier epoch where it is stated that Kṛttikā never swerve from the east. This correspond to 2950 BC. The Maitrayānīya Brāhmaṇa Upaniṣad (6.14) refers to the winter solstice being at the mid-point of the Śraviṣṭhā segment and the summer solstice at the beginning of Maghā. This indicates 1660 BC.

The Vedāṅga Jyotiṣa (Yajur 6-8) mentions that winter solstice was at the beginning of Śraviṣṭhā and the summer solstice at the mid-point of Aśleṣā. This corresponds to about 1350 BC.<sup>24</sup>

In TS 7.4.8 it is stated that the year begins with the full moon of Phālgunī. In the Vedāṅga Jyotiṣa, it begins with the full moon in Maghā, providing further evidence forming a consistent whole.

The Śatapatha Brāhmaṇa story of the marriage between the Seven Sages, the stars of the Ursa Major, and the Kṛttikās is elaborated in the Purāṇas where it is stated that the ṛṣis remain for a hundred years in each nakṣatra. In other words, during the earliest times in India there existed a centennial calendar with a cycle of 2,700 years. Called the Saptarṣi calendar, it is still in use in several parts of India. Its current beginning is taken to be 3076 BC, but the notices by the Greek historians Pliny and Arrian suggest that, during the Mauryan times, this calendar was taken to begin in 6676 BC.

## Babylonian Astronomy

Our knowledge of Babylonian astronomy comes from three kinds of texts. In the first class are: (i) astronomical omens in the style of *Enūma Anu Enlil* (“when the gods Anu and Enlil”) that go back to the second millennium BC in a series of 70 tablets; (ii) the two younger Mul Apin tablets which is more astronomical; (iii) royal reports on omens from 700 BC onwards.

The second class has astronomical diaries with excellent observations over the period 750 BC to AD 75. The third class has texts from the archives in Babylon and Uruk from the period of the last four or five centuries BC which deal with mathematical astronomy.

In late texts the ecliptic is divided into 12 zodiacal signs, each of length precisely 30 degrees. Aaboe has proposed<sup>25</sup> that the replacement of constellations by 30° segments took place in the fifth century BC.

Babylonian mathematics is sexagesimal, that is, it uses a place-value system of base 60. This is considered one of the characteristic features of the Babylonian mathematical tradition.

The Babylonian year began with or after vernal equinox. The calendar is lunar with a new month beginning on the evening when the crescent of the new moon becomes visible for the first time. A month contains either 29 days (hollow) or 30 days (full). Since 12 lunar months add up to only 354 days, an intercalary month was occasionally introduced. Starting mid-fifth century, the intercalations followed the Metonic cycle where every group of 19 years contained seven years with intercalary months.

In the late texts the ecliptic is divided into 12 zodiacal signs, each of length precisely 30 degrees (uš). The first list of stars which used the signs of the zodiac is dated to about 410 BC.

The zodiacal signs have much overlap with the Indian ones, but they appear from nowhere. We cannot, for example, understand the basis of goat-fish, whereas the goad-headed Prajāpati is one of the key stories in Vedic lore. These signs do not belong to the same type. They include furrow, hired hand, and star. They could not have served as the model for the Indian zodiacal names or the Greek ones because of their haphazard nature. On the other hand, they could represent memory of an imperfectly communicated Indian tradition which was adapted into the Babylonian system.

Table 3: The Zodiac signs

<i>Latin</i>	<i>Babylonian</i>	<i>Greek</i>
Aries	hun, lu (hired hand)	Krios (ram)
Taurus	múl (star)	Tauros (bull)
Gemini	mash, mash-mash (twins)	Didymoi (twins)
Cancer	alla <sub>x</sub> , kušu (?)	Karkinos (crab)
Leo	a (lion)	Leon (lion)
Virgo	absin (furrow)	Parthenos (virgin)
Libra	rín (balance)	Khelai (claws)
Scorpio	gír (scorpion)	Skorprios (scorpion)
Sagittarius	pa (name of a god)	Toxotes (archer)
Capricornus	máš (goat-fish)	Aigokeros (goat-horned)
Aquarius	gu (?)	Hydrokhoos (water-pourer)
Pisces	zib, zib-me (tails)	Ikthyes (fishes)

The Babylonians had two systems to place the signs on the ecliptic. In one, the summer solstice was at  $8^\circ$  in kušu (and the winter solstice in  $8^\circ$  in máš); in another system, the solstices were at  $10^\circ$  of their signs. They measured the moon and the planets from the ecliptic using a measure called *she*, equal to  $1/72$  of a degree.

They appear to have used two models for the sun's motion. In one, the sun's velocity changes suddenly; in another, it goes through a zig-sag change.

As far as planets are concerned, they calculated the dates of the instants the planet starts and ends its retrogression, the first visible heliacal rising, the last visible heliacal rising, and opposition. They also computed the position of the planet on the ecliptic at these instants. In the planetary theory, the synodic month is divided into 30 parts, which we now call *tithi* from its Indian usage.

In the Babylonian planetary models the concern is to compute the time and place of first stationary points. Two different theories to do this were proposed which have been reconstructed in recent decades.<sup>26</sup>

## Babylonian Astronomy and the Vedāṅga Jyotiṣa

The thesis that Babylonian astronomy may have led to Vedic astronomy was summarized in the following manner by David Pingree:<sup>27</sup>

Babylonian astronomers were capable of devising intercalation-cycles in the seventh, sixth, and fifth centuries B.C., and there is evidence both in the Greek and in the cuneiform sources that they actually did so; and by the early fourth century B.C. they had certainly adopted the quite-accurate nineteen-year cycle. It is my suggestion that some knowledge of these attempts reached India, along with the specific astronomical material in the fifth or fourth century B.C. through Iranian intermediaries, whose influence is probably discernible in the year-length selected by Lagadha for the *Jyotiṣavedāṅga*. But the actual length of the yuga, five years, was presumably accepted by Lagadha because of its identity with a Vedic lustrum. Not having access to a series of extensive observations such as were available to the Babylonians, he probably was not completely aware of the crudeness of his system. And the acceptance of this cycle by Indians for a period of six or seven centuries or even more demonstrates among other things that they were not interested in performing the simplest acts of observational astronomy.

The specific items from Babylonian astronomy that Pingree believes were incorporated into the “later” Vedic astronomy are :

1. The ratio of 3:2 for the longest to the shortest day used after 700 BC.
2. The use of a linear function to determine the length of daylight in intermediate months.
3. The use of the water-clock.
4. The concept of the *tithi* as the thirtieth part of the lunar month.
5. The use of two intercalary months in a period of 5 years.
6. The concept of a five-year yuga.

Each of these points has been answered by several historians. In particular, T.S. Kuppanna Sastry wrote a much-acclaimed text on the Vedāṅga Jyotiṣa showing how it supports its dating of around 1300-1200 BC. In fact, in his classic *Bhāratīya Jyotiṣa* (1896), S.B. Dīkṣita had already documented the Vedic roots of Vedic astronomy. More recently, Achar<sup>28</sup> has dealt with these questions at length in his paper on the Vedic origin of ancient mathematical astronomy in India.

### Length of the Day

The proportion of 3:2 for the longest to the shortest day is correct for north-west India. On the other hand, the Babylonians until 700 BC or so used the incorrect proportion of 2:1. It is clear then that the Babylonians for a long time used a parameter which was completely incorrect. They must have, therefore, revised this parameter under the impulse of some outside influence.

In any event, the 3:2 proportion proves nothing because it is correct both for parts of India and Babylon. Its late usage in Babylonia points to the limitations of Babylonian observational astronomy before 700 BC.

### The Use of a Linear Function for Length of Day

The interpolation formula in the Ṛgjyotiṣa, verse 7, is:

$$d(x) = 12 + 2x/61$$

where  $d$  is the duration of day time in muhūrtas and  $x$  is the number of days that have elapsed since the winter solstice.

The use of this equation is natural when one considers the fact that the number of muhūrtas required for the winter solstice for the 3:2 proportion to hold is 12. This ensures that the length of day and night will be equal to 15 muhūrtas each at the equinox.

The Taittirīya Saṃhitā 6.5.3.4 speaks clearly of the northern and southern movements of the sun: *ādityaḥṣaṇmāso dakṣiṇenaiti śaḍuttareṇa*.

The Brāhmaṇas count days starting from the winter solstice and the period assumed between the two solstices is 183 days. It is natural to adopt the equation given above with these conditions which are part of the old Vedic astronomical tradition. Use of it in either region does not imply borrowing because it is the most obvious function to use.

### The Use of the Water Clock

The use of the water-clock occurs in the Atharvaveda 19.53.3 in the expression:<sup>29</sup>

*pūrṇaḥ kumbho'dhi kāla āhitaḥ*: A full vessel is placed upon kāla (time).

The objective of this mantra is to exhort that “a full vessel be set [up] with reference to the [measurement of] time.”

Since the Atharvaveda is prior to the period of Babylonian astronomy by any account, it shows that India used water-clocks. Babylonia may have had its own independent tradition of the use of water-clocks.

### The Concept of *tithi*

The division of year into equal parts of 30 portions is to be found in several places in the Vedas and the subsequent ancillary texts.

In (RV 10.85.5), it is stated that the moon shapes the year. In Taittirīya Brāhmaṇa the correct technical sense of *tithi* is given at many places. For example, in 1.5.10, it is said that *candramā vai pañcadaśaḥ. eṣa hi pañcadaśyāmapakṣīyate. pañcadaśyāmāpūryate*, “the moon wanes in fifteen, and waxes in fifteen [days].” In 3.10, the fifteen *tithis* of the waxing moon and fifteen *tithis* of the waning moon are named.

The idea of a *tithi* is abstract. There are only 27 moonrises in a month of 29.5 days. To divide it into 30 parts means that a *tithi* is smaller than a day. The reason it arose in India was due to its connection to Soma ritual.

The number 360 is fundamental to Vedic thought. It represents the equivalence between time and the subject. In Āyurvda, the number of bones of the developing fetus are taken to be 360.

Since all the six concepts were already in use in the Saṃhitās, in an epoch earlier than 1000 BC in the least, they could not have been learnt by the Indians from the Babylonians who came to use these concepts after 700 BC.

## Babylonian Observations and Siddhāntic Astronomy

Another issue related to the possible connection between Babylonian and Indian astronomy is whether the excellent observational tradition of the Baby-

Ionians was useful to the Indians. Were ideas at the basis of Āryabhaṭa's astronomy were borrowed from outside or were part of India's own tradition. A few years ago,<sup>30</sup> Abhyankar argues that "Āryabhaṭa's values of *bhagaṇas* were probably derived from the Babylonian planetary data." But Abhyankar makes contradictory assertions in the paper, suggesting at one place that Āryabhaṭa had his own observations and at another place that he copied numbers without understanding, making a huge mistake in the process.

In support of his theory, Abhyankar claims that Āryabhaṭa used the Babylonian value of 44528 synodic months in 3600 years as his starting point. But this value is already a part of the Śatapatha altar astronomy reconciling lunar and solar years in a 95-year yuga. In this ritual, an altar is built to an area that is taken to represent the nakṣatra or the lunar year in tithis and the next design is the same shape but to a larger area (solar year in tithis), but since this second design is too large, the altar construction continues in a sequence of 95 years. It appears that satisfactory reconciliation by adding intercalary months to the lunar year of 360 tithis amounted to subtracting a certain number of tithis from the 372 tithis of the solar year, whose most likely value was 89 tithis in 95 years.<sup>31</sup>

The areas of the altars increase from  $7\frac{1}{2}$  to  $101\frac{1}{2}$  in the 95 long sequence in increments of one. The average size of the altar is therefore  $54\frac{1}{2}$ , implying that the average difference between the lunar and the solar year is taken to be one unit with  $54\frac{1}{2}$  which is about 6.60 tithis for the lunar year of 360 tithis. This is approximately correct.

Considering a correction of 89 tithis in 95 years, the corrected length of the year is  $372 - 89/95 = 371.06316$  tithis. Since each lunation occurs in 30 tithis, the number of lunations in 3600 years is 44527.579. In a Mahāyuga, this amounts to 53,433,095. In fact, the number chosen by Āryabhaṭa (row 1 in Table 4) is closer to this number rather than the Babylonian number of 53,433,600. One may imagine that Āryabhaṭa was creating a system that was an improvement on the earlier altar astronomy.

Table 4 presents the Babylonian numbers given by Abhyankar together with the Āryabhaṭa constants related to the synodic lunar months and the revolutions of the lunar node, the lunar apogee, and that of the planets. It should be noted that the so-called Babylonian numbers are not actually from any Babylonian text but were computed by Abhyankar using the rule of three on various Babylonian constants.



Table 4: Reconstructed Babylonian and Āryabhaṭa parameters

Type	Babylonian	Āryabhaṭa
Synodic lunar months	53,433,600	52,433,336
Lunar node	-232,616	-232,352
Lunar apogee	486,216	488,219
Mercury	17,937,000	17,937,020
Venus	7,022,344	7,022,388
Mars	2,296,900	2,296,824
Jupiter	364,216	364,224
Saturn	146,716	146,564

We see that no numbers match. How does one then make the case that Āryabhaṭa obtained his numbers from a Babylonian text? Abhyankar says that these numbers are different because of his (Āryabhaṭa's) own observations “which are more accurate.” But if Āryabhaṭa had his own observations, why did he have to “copy” Babylonian constants, and end up not using them, anyway?

Certain numbers have great discrepancy, such as those of the lunar apogee, which Abhyankar suggests was due to a “wrong reading of 6 by 8” implying—in opposition to his earlier view in the same paper that Āryabhaṭa also had his own observations—that Āryabhaṭa did not possess his own data and that he simply copied numbers from some manual brought from Babylon!

The Āryabhaṭa numbers are also more accurate than Western numbers as in the work of Ptolemy.<sup>32</sup> Given all this, there is no credible case to accept the theory of borrowing of these numbers from Babylon.

Abhyankar further suggests that Āryabhaṭa may have borrowed from Babylon the two central features of his system: (i) the concept of the Mahāyuga, and (ii) mean superconjunction of all planets at some remote epoch in time. In fact, Abhyankar repeats here an old theory of Pingree<sup>33</sup> and van der Waerden<sup>34</sup> about a transmission from Babylon of these two central ideas. Here we show that these ideas were already present in the pre-Siddhāntic astronomy and, therefore, a *contrived* connection with Babylonian tables is unnecessary.

In the altar ritual of the Brāhmaṇas,<sup>35</sup> equivalences by number connected the altar area to the length of the year. The 5-year yuga is described in the

Vedāṅga Jyotiṣa, where only the motions of the sun and the moon are considered. The Śatapatha Brāhmaṇa describes the 95-year cycle to harmonize the solar and the lunar years. The Śatapatha Brāhmaṇa also describes an asymmetric circuit for the sun<sup>36</sup>, which the Greeks speak about only around 400 BC.

Specifically, we find mention of the nominal year of 372 tithis, the nakṣatra year of 324 tithis, and a solar year of 371 tithis. The fact that a further correction was required in 95 years indicates that these figures were in themselves considered to be approximate.

In the altar ritual, the primal person is made to an area of  $7\frac{1}{2}$  puruṣas, when a puruṣa is also equated with 360 years leading to another cycle of 2700 years. This is the Saptarṣi cycle which was taken to start and end with a superconjunction.

The Śatapatha Brāhmaṇa 10.4.2.23-24 describes that the Ṛgveda has 432,000 syllables, the Yajurveda has 288,000 and the Sāmaveda has 144,000 syllables. This indicates that larger yugas in proportion of 3:2:1 were known at the time of the conceptualization of the Saṃhitās.

Since the nominal size of the Ṛgveda was considered to be 432,000 syllables (SB 10.4.2.23) we are led to the theory of a much larger yuga of that extent in years since the Ṛgveda represented the universe symbolically.

Van der Waerden<sup>37</sup> has speculated that a primitive epicycle theory was known to the Greeks by the time of Plato. He suggested such a theory might have been known in the wider Indo-European world by early first millennium BC. With new ideas about the pre-history of the Indo-European world emerging, it is possible to push this to an earlier millennium. An old theory may be the source which led to the development of very different epicycle models in Greece and India.

The existence of an independent tradition of observation of planets and a theory thereof as suggested by our analysis of the Śatapatha Brāhmaṇa helps explain the puzzle why the classical Indian astronomy of the Siddhānta period uses many constants that are different from those of the Greeks.

## More on the Great Year

Since the yuga in the Vedic and the Brāhmaṇa periods is so clearly obtained from an attempt to harmonize the solar and the lunar years, it appears that

the consideration of the periods of the planets was the basis of the creation of an even longer yuga.

There is no reason to assume that the periods of the five planets were unknown during the Brāhmaṇa age. I have argued that the astronomical numbers in the organization of the Ṛgveda indicate with high probability the knowledge of these periods in the Ṛgvedic era itself.<sup>38</sup>

Given these periods, and the various yugas related to the reconciliation of the lunar and the solar years, we can see how the least common multiple of these periods will define a still larger yuga.

The Mahābhārata and the Purāṇas speak of the kalpa, the day of Brahmā, which is 4,320 million years long. The night is of equal length, and 360 such days and nights constitute a “year” of Brahmā, and his life is 100 such years long. The largest cycle is 311,040,000 million years long at the end of which the world is absorbed within Brahman, until another cycle of creation. A return to the initial conditions (implying a superconjunction) is inherent in such a conception. Since the Indians and the Persians were in continuing cultural contact, it is plausible that this was how this old tradition became a part of the heritage of the Persians. It is not surprising then to come across the idea of the World-Year of 360,000 years in the work of Abū Ma’shar, who also mentioned a planetary conjunction in February 3102 BC.

The theory of the transmission of the Great Year of 432,000 years, devised by Berossos, a priest in a Babylonian temple, to India in about 300 BC, has also been advanced. But we see this number being used in relation to the Great Year in the Śatapatha Brāhmaṇa, a long time before Berossos.

The idea of superconjunction seems to be at the basis of the cyclic calendar systems in India. The Śatapatha Brāhmaṇa speaks of a marriage between the Seven Sages, the stars of the Ursa Major, and the Kṛttikās; this is elaborated in the Purāṇas where it is stated that the ṛṣis remain for a hundred years in each nakṣatra. In other words, during the earliest times in India there existed a centennial calendar with a cycle of 2,700 years. Called the Saptarṣi calendar, it is still in use in several parts of India. Its current beginning is taken to be 3076 BC.

The usage of this calendar more than 2000 years ago is confirmed by the notices of the Greek historians Pliny and Arrian who suggest that, during the Mauryan times, the Indian calendar began in 6676 BC. It seems quite certain that this was the Saptarṣi calendar with a beginning which starts 3600 years earlier than the current Saptarṣi calendar.

The existence of a real cyclic calendar shows that the idea of superconjunction was a part of the Indic tradition much before the time of Berossos. This idea was used elsewhere as well but, given the paucity of sources, it is not possible to trace a definite place of origin for it.

## On Observations in Indian Astronomy

The use of the lunar zodiac creates complicating factors for observation which were not appreciated by early historians of Indian astronomy. Roger Billard's demonstration<sup>39</sup> of the falsity of the 19th century notion that India did not have observational astronomy has devastating consequences for the school-book histories of early astronomy. His analysis of the Siddhāntic and the practical karaṇa texts demonstrated that these texts provide a set of elements from which the planetary positions for future times can be computed. The first step in these computations is the determination of the mean longitudes which are assumed to be linear functions of time. Three more functions, the vernal equinox, the lunar node and the lunar apogee are also defined.

Billard investigated these linear functions for the five planets, two for the sun (including the vernal equinox) and three for the moon. He checked these calculations against the values derived from modern theory and he found that the texts provide very accurate values for the epochs when they were written. Since the Siddhānta and the karaṇa models are not accurate, beyond these epochs deviations build up. In other words, Billard refuted the theory that there was no tradition of observational astronomy in India. But Billard's book is not easily available in India, which is why the earlier theory has continued to do rounds in Indian literature.

Āryabhaṭa's constants are more accurate than the one's available in the West at that time. He took old Indic notions of the Great Yuga and of cyclic time (implying superconjunction) and created a very original and novel siddhānta. He presented the rotation information of the outer planets with respect to the sun – as was done by the śīghroccas of Mercury and Venus for the inferior planets – which means that his system was partially heliocentric.<sup>40</sup> Furthermore, he considered the earth to be rotating on its own axis. Since we don't see such an advanced system amongst the Babylonians prior to the time of Āryabhaṭa, it is not reasonable to look outside of the Indic tradition or Āryabhaṭa himself for the data on which these ideas were based.

The observational protocols used in Indian astronomy has become an interesting question to be investigated further.

## Conclusions

The debate on the relationship between the astronomical sciences of India and Babylon became vitiated by the theories of 19th century Indologists motivated by reasons of empire and race rather than scholarship. Furthermore, their analysis was done using simplistic ideas about cultural interaction. They took knowledge to flow from one direction to another without recognizing that the reality was likely to have been complex and interaction bidirectional. Considering that a time range of several centuries was involved and interaction through intermediaries constituted a complex process, the answer to any question of borrowings and influence can only be complicated.

Our review of Indian astronomy shows that in the period of the early Vedic texts, that are definitely prior to 1000 BC, the following facts were known:

- Vedic astronomy tracked the motion of the sun and the moon against the backdrop of the nakṣatras. The sky was divided into 12 segments (Ādityas) and 27 segments (lunar nakṣatras) where the nakṣatra and deity names were used interchangeably.
- Although the names of the solar zodiacal signs (rāśis) are seen first in the siddhāntic texts, we see they can be derived from the deity names of the lunar nakṣatra segments. Given that the nakṣatra names are to be found in the Śmhitās and the rāśi names are not in the Vedic books, one may conclude that the specific names were chosen sometime in the first millennium BC, replacing the earlier Āditya names. But the solar signs were a very early component of Vedic astronomy, acknowledged in the Ṛgvedic hymn itself which speaks of the twelve division of the 360-part wheel of time.
- Astrology (Jyotṣa) is a part of the earliest Vedic texts. Vedic ritual is associated with the time of the day, the nakṣatras, and the position of the moon. The year is divided into the deva nakṣatras and

yama nakṣatras and this division is carried down to smaller scales, implying that certain time durations are more auspicious than others. The meanings of the nakṣatras (such as Anurādhā, “propitious,” and Punarvasū, “giving wealth”) provide us evidence that they had an astrological basis. Vedic nakṣatras are assigned different qualities and in the marriage ritual the astrologer recommended an auspicious time. Taittirīya Brāhmaṇa 3.1.4 lists the effects of propitiating the different nakṣatras.

The fundamental notion in Vedic thought is the equivalence or connection (*bandhu*) amongst the adhidaiva (*devas* or stars), adhibhūta (beings), and adhyātma (spirit). These connections, between the astronomical, the terrestrial, the physiological and the psychological, represent the subtext without which the Vedas cannot be understood. These connections are usually stated in terms of vertical relationships, representing a recursive system; but they are also described horizontally across hierarchies where they represent metaphoric or structural parallels. Most often, the relationship is defined in terms of numbers or other characteristics. An example is the 360 bones of the infant—which later fuse into the 206 bones of the adult—and the 360 days of the year. Likewise, the tripartite division of the cosmos into earth, space, and sky is reflected in the tripartite psychological types.<sup>41</sup>

The bandhu are the rationale for astrology. Indeed, they inform us that astrology central to the world-view of the Indians.

- The use of the tithi system, the division of the lunar month into 30 parts, is closely connected to Soma worship, a uniquely Indian ritual. There is no such ritual connection with the tithis that we know of in the Babylonian context.

The evidence suggests that the Indian ideas of sacrifice, 12 divisions of the solar year, and the 30 divisions of the lunar month, and the zodiac reached Babylonia around the middle of the first millennium BC. These new ideas, including the Indian ratio of 3:2 for the longest to shortest day of the year, triggered a new phase of careful observations in Babylonia which were to influence astronomy in a fundamental way.

But it is also possible that the Babylonian flowering was quite independent based on the presence of general ideas which were present in the lands

across India to Greece. In any event, the borrowing was of the most general ideas, the detailed methods reflected the local genius. This is the reason that the details that we find in the astronomical systems of India and Babylon (and also Greece) have unique features.

Astrology was a part of the ancient world everywhere including Mesopotamia. But it appears that the solar zodiacal signs as we know them originated in India, where they have a relationship with the deities of the nakṣatras, and were later adopted in Babylonia in the middle of the first millennium BC and subsequently in Greece. But this does not mean that the detailed practice of Vedic astrology was adopted by the Babylonians.

Subsequent to the establishment of the Indo-Greek states on the borders of India after Alexander, the interaction between Indian and Western astrology and astronomy entered a new phase the details of which are not well understood. Increased political and trade interaction made it possible for texts to be exchanged.

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Why do serious scholars persist in believing in the Aryan invasions?... Why is this sort of thing attractive? Who finds it attractive? Why has the development of early Sanskrit come to be so dogmatically associated with an Aryan invasion?...

Where the Indo-European philologists are concerned, the invasion argument is tied in with their assumption that if a particular language is identified as having been used in a particular locality at a particular time, no attention need be paid to what was there before; the slate is wiped clean. Obviously, the easiest way to imagine this happening in real life is to have a military conquest that obliterates the previously existing population!

The details of the theory fit in with this racist framework... Because of their commitment to a unilineal segmentary history of language development that needed to be mapped onto the ground, the philologists took it for granted that proto-Indo-Iranian was a language that had originated outside either India or Iran. Hence it followed that the text of the Rig Veda was in a language that was actually spoken by



those who introduced this earliest form of Sanskrit into India. From this we derived the myth of the Aryan invasions. QED.

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