On Āryabhaṭa’s Planetary Constants

Subhash Kak∗

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Abstract

This paper examines the theory of a Babylonian origin of Āryabhaṭa’s planetary constants. It shows that Āryabhaṭa’s basic constant is closer to the Indian counterpart than to the Babylonian one. Sketching connections between Āryabhaṭa’s framework and earlier Indic astronomical ideas on yugas and cyclic calendar systems, it is argued that Āryabhaṭa’s system is an outgrowth of an earlier Indic tradition.

Keywords: Āryabhaṭa’s astronomy, Kaliyuga, Mahāyuga, synodic lunar months

1 Introduction

An old problem in the history of Indian science is whether ideas at the basis of Āryabhaṭa’s astronomy were borrowed from outside or were part of India’s own tradition. This problem was first raised in the context of the now discredited thesis that sound observational astronomy did not exist in India prior to India’s encounter with the West. Thus in a recent paper,1 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

∗Department of Electrical & Computer Engineering, Louisiana State University, Baton Rouge, LA 70803-5901, USA, Email: kak@ece.lsu.edu
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.2

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 1) is closer to this number rather than the Babylonian number of 53,433,600.

Table 1 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. 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.

| 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 observ-
ations “which are more accurate.” But if Āryabhaṭa had his own obser-
vations, 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 Baby-
lon!

The Āryabhaṭa numbers are also more accurate that Western numbers
as in the work of Ptolemy. 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
and van der Waerden about a transmission from Babylon of these two cen-
tral ideas. In this paper, we show that these ideas were already present in
the pre-Siddhāntic astronomy and, therefore, a contrived connection with
Babylonian tables is unnecessary.

2 The Indic tradition of yugas and superconjunctions

In the altar ritual of the Brāhmaṇas, 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, 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 cor-
rection was required in 95 years indicates that these figures were in them-
selves considered to be approximate.

In the altar ritual, the primal person is made to an area of 7½ puruṣas,
when a puruṣa is also equated with 360 years leading to another cycle of
2700 years. This is the Saptarshi cycle which was taken to start and end with a superconjunction.

The Sātapatha Brāhmaṇa 10.4.2.23-24 describes that the Rgveda has 432,000 syllables, the Yajurveda has 288,000 and the Śāmaveda 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 Śaṁhitās.

Since the nominal size of the Rgveda 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 Rgveda represented the universe symbolically.

Elsewhere, I show how the Vedāṅga Jyotiṣa serves as a coordinate system for the sun and the moon in terms of the 27 nakṣatras. Such a coordinate system implies a calculation where whole cycles are subtracted from large numbers. Such modular arithmetic appears to lie at the basis of the idea of a superconjunction. Traditionally, the Vedāṅga Jyotiṣa has been dated to around 1350 BC, but a new paper by Narahari Achar argues for a much earlier date of 1800 BC.

Van der Waerden has argued that a primitive epicycle theory was known to the Greeks by the time of Plato. He argued 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 Sātapatha Brāhmaṇa helps explain the puzzle why the classical Indian astronomy of the Śiddhānta period uses many constants that are different from those of the Greeks.

3 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 Rgveda indicate with high probability the knowledge of these periods in the Rgvedic era itself.
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 certain that this old tradition became a part of the heritage of the Persians. This explains how we 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, was advanced by Pingree. But we see this number being used in relation to the Great Year in the Śatapatha Brāhmaṇa itself, 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 rṣis 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 BE.

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.
4 Conclusions

More than thirty years ago, Roger Billard showed\textsuperscript{14} the falsity of the 19th century notion that India did not have observational 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 with respect to the sun which means that his system was heliocentric to a certain extent.\textsuperscript{15} 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.

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