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BABYLONIAN SOURCE OF ĀRYABHAṬA'S PLANETARY CONSTANTS

K. D. ABHYANKAR*

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It is shown that Āryabhaṭa's values of *bhagaṇas* were probably derived from the Babylonian planetary data.

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1. INTRODUCTION

Siddhāntic astronomy is characterised by two important concepts, viz., Mahāyuga and mean superconjunction at the beginning of Kaliyuga. Mahāyuga consists of 43,20,000 years. This large number is used for avoiding the cumbersome system of representing quantities in sexagesimal system of Babylonians. For example, it is stated that the Babylonian year contained 12:22:08 synodic lunar months.[1] It amounts to (8 + 22 x 60 + 12 x 3600) / 3600 = 44528 / 3600 synodic lunar months in one year. We see that it is easier to say that there are 44528 synodic lunar months in 3600 years, instead of remembering three numbers 12, 22 and 8 with an involved calculation. As the planetary pheomena are not commensurate, one requires a large period like 43,20,000 years to express all of them in this way. This is the genesis of Mahāyuga.

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* Astronomy Department, Osmania University, Hyderabad - 500 007.

[1] O. Neugebauer, *A History of Ancient Mathematical Astronomy*, Berlin 1975.

The second concept introduced by Āryabhaṭa is the mean superconjunction of all planets at some remote epoch in time. This notion arose from the fact that the periods of synodic phenomena (opposition, conjunction etc.) can be determined more accurately if the observations are separated by a large number of repeated events.[2] Once the period is fairly well known, the discrepancy in actual position of the distant past event will not give rise to large error in the period, provided we have good observations for the current epoch to get error free position in the vicinity of that epoch. Hence there is no harm in assuming that all planets started from one fixed position in the remote past like the beginning of Mahāyuga or Kaliyuga. Consequently astronomers had to depend on new data after a reasonable lapse of time. This was the technique devised by Āryabhaṭa and followed later by Siddhāntic astronomers as shown by R. Billard.[3]

2. Lunar Ephemeris

Āryabhaṭa gives the *bhagaṇas,* i.e. the sidereal revolutions of the celestial objects in a Mahāyuga. For example, on applying the rule of three to the Babylonian value of 44528 synodic lunar months in 3600 years we get 53433600 synodic lunar months in a Mahāyuga. Adding 43,20,000 solar *bhagaṇas* we get sidereal lunar months in a Mahāyuga. Āryabhaṭa gives the value of 53433336 and 57753336 for them, respectively, which are more accurate as they are based on his observations made in 3600 Kali era. As it was assumed that the moon was at *Meṣādi* at the beginning of Kaliyuga, the difference of –264 revolutions indicates a difference of (–264 x 360 x 3600)/ 43,20,000 = –79^0.2 in the observed and the calculated positions of the moon at the time of observation.

Now the Babylonians also knew[4] that 223 synodic lunar months are equal to 242 Draconic months and 239 anomalistic months. Hence the rule of three gives 57985952 Draconic months and 57267118 anomalistic months in

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[2] K. Chanda Hari, "On the Origin of 'Kaliyugādi' Synodic Super Conjunction," IJHS, 33 (1998) 193-201.

[3] R. Billard, "Āryabhaṭa and Indian Astronomy," IJHS, 12(1977) 207-224.

[4] Neugebauer, op. cit.

a Mahāyuga. On taking the difference between these and sidereal months we get –232616 revolutions of lunar node and 486218 revolutions of the lunar apogee in a Mahāyuga. The values given by Āryabhaṭa are –232352 and 488219 respectively. The former is obtained by taking the Babylonian value of 57753600 for sidereal months in a Mahāyuga. But the difference in the latter is large and might be caused by a wrong reading of 6 by 8.

3. Planetary Ephemeris

Babylonian planetary tables are characterised by two numbers π and Z given in Table 1. Neugebauer calls π as the number period and Z as wave number. Actully π represents the number of synodic revolutions and Z is related to the corresponding sidereal revolutions, say S, as follows: S = Z for Jupiter and Saturn, $S = \pi + Z$ for Mercury and Mars, and $S = 2\pi + Z$ for Venus. S is given in column 4 of Table 1. Then the numbers of Y required for these

Table 1 : *Bhagaṇas* in a quarter *Mahāyuga*

Planets	π	Z	S	Y	B
Mercury	1513	480	1993	480	4484250
Venus	720	431	1871	1151	1755586
Mars	133	18	151	284	574225'
Jupiter	391	36	36	427	91054
Saturn	256	9	9	265	36679

Table 2 : *Bhagaṇas* in a *Mahāyuga*

Planets	Babylonian	Āryabhaṭa	Difference for 3600 years	Difference in degrees
Mercury	17937000	17937020	+ 0.01666	+ 6
Venus	7022344	7022388	+ 0.03666	+13.2
Mars	2296900	2296824	– 0.06333	–22.8
Jupiter	364216	364224	+ 0.00666	+ 2.4
Saturn	146716	146564	– 0.12666	–45.6

synodic and sidereal revolutions will be $S - \pi$ for Mercury and Venus and $S + \pi$ for the outer planets, as given in the 5th column. Using these values we get by the rule of three the *bhagaṇas* (B) in a quarter Mahāyuga equal to 10,80,000 x S/Y given in the last column. Finally multiplying by 4 we get the *bhagaṇas* in a Mahāyuga given in the second column of Table 2, which also gives Āryabhaṭa's *bhagaṇas* in column 3. The two values are nearly equal.

Now reducing the difference between the Babylonian and Āryabhaṭa's values of *bhagaṇas* by a factor of 1200, which is the ratio of the length of Mahāyuga (43,20,000 years) and the time elapsed from the beginning of Kaliyuga (3600 years) we get the figures in column 4 of Table 2. The last column expresses this difference in degrees (by multiplying with 360). This would be the difference between the observed and the calculated positions which would have been used by Āryabhaṭa to correct the Babylonian values of *bhagaṇas*.

4. Conclusion

The Mahāyuga of 4.32×10^6 years was found to be adequate for expressing the *bhagaṇas* for the short period phenomena in integral numbers. But the slow moving nodes of the planetary orbits required a larger time span. This necessitated the introduction of Kalpa of 4.32×10^9 years equal to 1000 Mahāyugas. However Āryabhaṭa considered both of them as mathematical artifacts for simplifying astronomical computations. He did not associate them with the creation and evolution of the universe as envisaged in the Purāṇas[5].

It may be noted that there was an exchange of ideas between Indian and Babylonian astronomers in the pre-Siddhāntic period. For example, the Babylonians took the notion of *tithi* as a time marker from *Vedāṅga Jyotiṣa*, while the Indians took the planetary periods from the Babylonians. It is likely that Siddhāntic methods were developed through this interaction without the Greek intermediaries. The variable size of epicycles found in the Indian system could be reminiscent of the zigzag functions of the Babylonians.

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[5] K. S. Shukla and K. V. Sarma. tr, *Āryabhaṭīya of Āryabhaṭa*. New Delhi 1976, p. xxx.