Indian Journal of History of Science, 37.2 (2002) 101-113

GENESIS AND ANTECEDENTS OF ĀRYABHAṬĪYA

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(Received 27 January 2000)

In the present paper an attempt has been made to throw light on the true epoch of *Āryabhaṭīya* as well as the structure of the treatise. Based on the clue of the stationary aphelion, the original Hindu zero point as well as the zodiac have been deciphered. It would seem that the *Āryabhaṭīya* astronomy evolvd out of the sidereal astronomy of Tāntric cults. Based on the astronomical interpretation of the iconography of Rudra the original epoch of Tāntric astronomy can be indentified as 4137 BC. A sequence of seven lunations marked the boundaries of sidereal zodical signs from Kanyā Mīna 4137 BC. A sequence of seven lunations marked the boundaries of sidereal zodiacal signs from Kanyā and Mīna in 4137 BC and this luni-solar phenomenon recurred with a periodicity of 160 years. *Āryabhaṭan* astronomy evolved out of the indigenous sideral astronomy by incorporating the Greek concepts with appropriate modifications.

Key words: *Āryabhaṭīya* – anomalistic zodiac, genesis and structure, Kali epoch, *Mūlādhāra-cakra* epoch, Siddhāntic zero point.

INTRODUCTION

The *Āryabhaṭīya* is an immortal creation of Indian genius and 1500 years have passed since its formulation. Astronomical theory and mathematical technique employed by Āryabhaṭa have undergone detailed studies in the light of modern science during the last two centuries. The treatise is available with translation and elaborate notes by two eminent scholars, K. S. Shukla and K. V. Sarma, published by the Indian National Science Academy[1]. Further, an exhaustive account of the notable features of Āryabhaṭa astronomy can be found in the proceedings of the symposium held on the 1500th birth anniversary of Āryabhaṭa[2]. But little is known about the author himself and the Ācāryas who preceded him as well as the

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genesis of the theory he has given and its *apauruseya* background of the *Svāyamnbhūva-siddhānta*[3]. Controversies regarding the place of Āryabhaṭa, the epochs that his treatises have presented, solar year and the consequent anomalous structure of *Āryabhaṭīya* etc. still remain problematic.

As the present author understands, there remains nothing new to be written about the ingenuity of Āryabhaṭa's techniques or the innovations he has brought in that the earlier authors have not touched upon in the above cited reference[1,2,4]. Repetition of such accounts already available in the literature or stereotype studies tend to shy away from the controversial aspects mentioned above. Rather, we must ask ourselve as to what did we learn new about Āryabhaṭa or his astronomy or Indian astronomy in general, since the celebration of Āryabhaṭa or his astronomy or Indian astronomy in general, since the celebration of Āryabhaṭa's 1500th birth anniversary in 1977. As such in the present work, effort will be to touch upon the aforesaid controversial aspects to gain some insights regarding the astronomical background that gave shape to *Āryabhaṭīya* as well as its anomalous zodiac. In the following discussion we shall designate all epochs as Kali year (elapsed) with the notation K and the elapsed year as a subscript.

Epoch of Āryabhaṭīya = K_{3600} or K_{3623} ?

The *Āryabhaṭīya* III.10 had a disputed interpretation even in the days of classical commentators. Literary interpretation tend to suggest K_{3600} as the year of formulation of *Āryabhaṭīya* at Āryabhaṭa's age of 23 but the Kerala tradition[5] renders evidence towards K_{3623}. Calendar Reform Committee had taken K_{3600} and ascribed an error of almost 18′ for the mean Sun of *Āryabhaṭīya* without examining the possibility of K_{3623} being the true epoch. Following the general approach, the veracity of these variant interpretations can be ascertained by a comparison of the mean orbital elements as per *Āryabhaṭīya* and modern astronomy for the above epochs.

It is apparent from the above that the Kerala tradition is founded on strong astronomical evidence and the mean Sun as per *Āryabhaṭīya* corresponding to the expiry of the Kali year coincided with vernal equinox for K_{3623}. In the *Siddhāntic* astronomy tradition there is no specific definition

or even a mention of the zero point other than the mean Sun corresponding to the expiry of respective Kali year. We can find an echo of this fact in the following words of Rev. E. Burgess[6]:

TABLE 1 : MEAN ORBITAL ELEMENTS OF K_{3600} AND K_{3623}

Planet	*K_{3600}		**K_{3623}	
	Āryabhaṭīya	Modern Astronomy	*Āryabhaṭīya*	Modern Astronomy
Mean Sun	0°	359°40′	0°	0°02′
Apogee (Sun)	78°	77°14′	78°	77°35′
Mean Moon	280°48′	279°21′	94°42′	93°36′
Apogee (Moon)	35°42′	35°26′	251°27′	251°23′
Node (Moon)	352°12′	352°01′	267°06′	267°08′
Mean Mars	07°12′	06°51′	89°27′	89°33′
Aphelion (Mars)	118°	128°28′	118°	128°53′
Node (Mars)	40°	37°58′	40°	38°09′
Mean Mercury	186°00′	183°00′	05°17′	02°51′
Aphelion (Merc.)	210°	234°10′	210°	234°31′
Node (Merc.)	20°	30°34′	20°	30°53′
Jupiter-mean	187°12′	187°09′	165°18′	165°31′
Aphelion (Jupiter)	180°′	170°23′	180°	170°44′
Node (Jupiter)	80°	85°14′	80°	85°28′
Venus-mean	356°24′	356°04′	135°59′	135°48′
Aphelion (Venus)	90°	110°18′	90°	110°38′
Node (Venus)	60°	63°15′	60°	63°27′
Saturn-mean	49°12′	48°23′	330°07′	329°47′
Aphelion (Saturn)	236°	243°45′	236°	244°12′
Node (Saturn)	100°	100°29′	100°	100°41′

*$K_{3600} = K_0 + 365.2586806x\ 3600$

**$K_{3623} = K_0 + 365.2586806 \times 3623$

where K_0 is taken as 17/18 Feb 3102 BC 0530 (IST) - slightly earlier to the precise time of Sunrise at Ujjain.

"We have seen, in treating of the *Bīja*, that it has been the aim of the modern Hindu astronomers, leaving the Sun's errors untouched, to amend those of the other planets to and accordance with it..."

The Siddhāntic zero point and its relation to equinox was obviously governed by the fictitious epoch K_0 and the length of the solar year. Traditionally K_0 meant the Ujjain midnight of 17/18 February 3102 BC wherein occurred a mean synodic super conjunction of the *"aṣṭa-graha:"* at the first point of Meṣa. The year length of *Āryabhaṭīya*, i.e. 365.2586806 days corresponded to the coincidence of mean Sun with the mean equinox of K_{3623}.

Mean positions have only mathematical existence and *Āryabhaṭīya* could not have observed them. It is evident from *Āryabhaṭīya* (1.3 & 4) that *Āryabhaṭīya* deduced the epoch K_0 (*Kaliyugādi*) from his observation of the true vernal equinox of K_{3623} on 19 March 522 AD 0859 (IST). Weekday was Saturday and so he arrived at the beginning of Kaliyuga or the synodic superconjunction by counting 3623 years = 1323332.2 back to reach the Sunrise of Wednesday a stated in the *Gītikā*-4. Or if we take his epoch as K_{3600}, he would have based his computations on the true equinox of 19 March 499 AD 1924 (IST), Friday and as such it was not possible to deduce K_0 as the Sunrise of Wednesday. The relevant astronomical data are given below:

K_0 = 16 February 3102 BC, Wednesday Sunrise at Ujjain. For computational convenience we take the epoch as at 0530 IST corresponding to the Julian Date (JD) of 588463.5.

Spring equinox of 522 AD, JD = 1911795.645. Counting back by 1323332.2 days leads us to JD = 588463.445 while if we go back from the spring equinox of AD 499 (JD = 1903395.079) by 1314931.25 days we reach 588463.829. With AD499, Āryabhaṭa could have deduced K_0 as at Wednesday Sunrise only by an error of more than six hours in the observation of true equinox, where as with AD 522 the offset is only two hours.

Table 1 is illustrative of the astonishing accuracy with which he had deduced the mean longitudes of planets from the observed true positions.

ANOMALOUS STRUCTURE AND THE GENESIS OF ĀRYABHAṬĪYA

With either of the aforesaid equinoxes as his reference it is evident that Āryabhaṭa had remarkable accuracy in fixing the true equinox. But in the years that followed we can find that the mean Sun of *Āryabhaṭīya* was drifting away from the equinox at the rate of approximately one minute of arc per year or one day in 60 years. This intricacy raises a number of questions as to the physical conceptions that formed the basis of the formulation of *Āryabhaṭīya*:

(a) Whether *Āryabhaṭīya* intended the equinox to be the zero point or not? If yes, how could he reconcile with an extra-long sidereal year despite his access to the shorter value of Romaka?

(b) Was he weak in observation as to be unaware of the precession of the equinoxes relative to his "solar" zero point corresponding to the expiry of the respective Kali year? (It may be remembered here that Muñjāla could accurately discern it after four centuries in K_{4033})

(c) How could Āryabhaṭa conceive that the vernal equinox marked the beginning of Meṣa / Aśvinī in the subsequent period?

(d) Not only Āryabhaṭa but also Brahmagupta professed a tropical zodiac (Vernal equinox at the beginning of Meṣa / Aśvinī) with an extra long sidereal year (365.2584375). It must be noted that Brahmagupta had to reduce the length of the solar year to achieve the coincidence of the mean Sun with the vernal equinox. If such modifications have been a regular feature, what could have been the original solar year of *Svāyambhūva-siddhānta* which both Āryabhaṭa and Brahmagupta have relied upon in formulating their treatises?

(e) Before the advent of *Brāhmasphuṭa-Siddhānta* of Brahmagupta with the reduced solar year, *Revati* (Zeta Piscium) equinox could not have been the zero point of *Siddhāntic* astronomy. Brahmagupta, zero point also had a progressive motion towards east by virtue of the surplus of the solar year over the true sidereal year and by the time of Bhāskara II it was $1^{0}9'$ ahead of its position at the time of Brahmagupta.

The obvious conclusion is that the *Siddhāntic* Zodiac in general and that of Āryabhaṭa was a zoidiac that had a mix-up of the anomalistic and tropical zodiacs.

(f) The extra-long sideral year of 365.2586806 days or 365.25875 days, that we see in Siddhāntic astronomy as related to the epoch of Āryabhaṭa K_{3623}/K_{3600} is only little shorter than the anomalistic year of 365.25963 days. Can this decrement be just accidental or a reduction of the true anomalistic value of Āryabhaṭa to suit the solar year to his epochal equinox as was done by Brahmagupta later on[7]?

Anomalistic Zodiac of Āryabhaṭa

Āryabhaṭīya stipulates stationary aphelion and as such strictly speaking Āryabhaṭa's Zodiac is anomalistic. Once the solar aphelion is fixed, if the framework of Āryabhaṭa's astronomy had a fixed zero point it must be of a constant mean anomaly since the K_0 epoch. Mean anomaly of Sun at K_0 was roughly $105^0 16'$.In other words for any treatise that postulates stationary aphelion and a fixed zero point at K_0, the zero difference *(ayanāṃśa)* year relative to the vernal equinox would have occurred in AD 238 (K_{3339}) where-in the spring equinox had the aforesaid constant anomaly.

i.e. $K_0 - K_{3339} = 3339$ true anomalistic years

The reduction that we see in Āryabhaṭa's solar year was probably a consequence of his effort to adopt the original *Svāyaṃbhīwa-Siddhānta*[3] to his epoch of K_{3623}/K_{3600} in a tropical fashion with the vernal equinox as the zero point. The Sun's errors remained untouched in the subsequent period as the solar position at the initial point i.e. *Meṣādi* was identified the terms of its true motion. With the nearly anomalistic year the true motion remained constant at the successive year-beginnings and thus the precession got over looked in the immediate vicinity of the epoch he had fixed.

Had the original *Svāyaṃbhīwa-Siddhānta* been using the anomalistic year, the correction required for the sidereal initial point was approximately (-) 9 seconds of arc per year or 30 revolutions of the *bhacakra* in a Mahāyuga of 4320000 years. Bhāskara II has referred to this aspect and a discussion over the same can be seen in the *Bhāratīya-Jyotiḥśāstra* Vol. II by S. B. Dikshit[8].

Bhāskara II's reference of such a practice assumes great significance against the backdrop of the above conjectures. Āryabhaṭa probably discarded such practices due to his reliance on the true motion of Sun in ascertaining its position and also because of the lack of long term astronomical observations. Present author has illustrated elsewhere[9] the *Siddhāntic* methodology of deriving the integral number of revolutions with short term observations of the synodic phenomena i.e. movement of the planets relative to Sun.

ANTECEDENTS OF ĀRYABHAṬA

As explained earlier *Āryabhaṭīya* provides a clue regarding the original zero point of Hindu astronomy - the epoch K_0 and the fixed aphelion suggest the existence of an original school which had its zero point coinciding with the vernal equinox of AD 238/K_{3339}. On examining the configuration of *Yogatārās* with reference to the above vernal equinox *vis-a-vis* the Hindu zero point, we find that the star *Mūla* (Lambda /Scorpii is precisely at 240^0 and thus qualifies to be the fiducial/fixed reference star. This identification of *Mūla* as the fiducial star receives corroborative support from the *Tāntric* concept of '*Mūlādhāra*' which in fact, literally mean – "*Mūla*, the fiducial". Further by the principle of symbolic equivalence of microcosm and macrocosm/Man and the Cosmos/*Jīvapurūṣa* and *Kālapūruṣa* (Zodiac), 240° location of *Mūla* corresponds to the bottom of the cerebro-spinal axis for which the *Tantric* terminology ascribe the term *Mūlādhāra*. As the fiducial star of *Kālacakra Mūla* had been the Crux of Time and hence the source of *Kuṇḍalinī* or horoscope in Jyotiḥśāstra. Similarly *Mūlādhāra* was the source of *Kuṇḍalinī-śakti* in Tantra. This synonymous phraseology that we see in Jyotiṣa and Tantra as well as the common source/Preceptor of these two disciplines, viz. Rudra, who is also known as *Mahākāla* (Great Time) renders strong support to the astronomical rationale ascribed to the *Tāntric* concept of *Mūlādhāra*. Further the scholars adept in Vedic mythology like A. J. Karandikar has identified Vedic Rudra as *Mūla* star and this identification finds further corroboration in the worship of *Mūla-Rudra* or Time (fiducial star of the Cycle of Time) as Phallus which again marks the position of 240^0 on the human zodiac. Details of this theory of *Mūlādhāra-Cakra* and its relation to the Babylonian as well as Vedic zodiac are under publication elsewhere[10, 11].

Original Epoch of Mūlādhāra-Cakra

Iconography of Rudra as having Sun, Moon and *Agni* as eyes, as the bearer of Crescent Moon and the Serpent etc., suggests the possibility of an astronomical epoch at which the new moon coincided with the autumnal equinox falling over *Mūla* at 240^0 degree of the sidereal zodiac. A search for the epoch using a latest program of the Bureau des Longitudes, Paris, led to the discovery of a zodiacal luni-solar phenomena centered over *Mūla* having a periodicity of 160 years. New moon/*Śuklapratipada* marked the solar ingress into the zodiacal signs of 30^0 beginning with *Kanyā* at intervals of 160 years prior to as well as after 4137 BC. The details of 4137 BC and 1944 AD (that comes after 38 periods of 160 sidereal years) are given below:

Table 2 : Luni-solar periodicity over the sidereal zodiac having *Mūla* at 240^0.

Rāśi and initial point (Sidereal)	JD for solar ingress 4137 BC	*Tithi* = (Moon-Sun)/12	Solar transit after 6080 sidereal years. 1944 AD	*Tithi* = (Moon-Sun)/12
Kanyā (Virgo, 150^0)	210590.4502 (Summer solstice)	29.65 (New moon)	2431350.3444	29.38 (New moon)
Tula (Libra, 180^0)	210620.5676	0.062 (*Śukla*-1)	2431380.809	0.067 (*Śukla*-1)
Vṛścika (Scorpio)	210650.1965	0.044 (*Śukla*-1)	2431410.806	0.346 (*Śukla*-1)
Dhanu (Sagittarius 240^0 - Mūla)	210679.5518 (Autumnal equinox)	29.79 New Moon	2431440.397	0.29 (*Śukla*-1)
Makara (Capricorn, 270^0)	210708.914	29.59 New moon	2431469.844	0.226 *Śukla*-1
Kumbhā (Aquarius 300^0)	210738.5612	29.82 New moon	2431499.35	0.135 *Śukla*-1
Mīna (Pisces, 330^0	210268.70573 (Winter solstice)	0.736 *Śukla*-1	2431529.266	0.719 *Śukla*-1

The epoch of 4137 BC thus had the coincidence of the tropical and sidereal year beginnings with either Summer solstice/*Kanyā* or Autumnal equinox/*Dhanu* or Winter solstice/*Mīna*. Tropical cardinal points gave rise to the vedic mythology of Indra (S. Solstice), Agni (A. Equinox), Varuṇa etc. with *Tāntric* mythology of *Durgā*, *Rudra* and Mahābalī took shape out of *Kanyā*, *Dhanu* and *Kumbha rāśis*, and other fixed signs such as Leo. Detailed analysis of mythology being outside the scope of the present paper, the conclusions arrived at elsewhere[12] and relevant to the present context are given below in brief:

(a) The legend of *Kanyākumāri vis-a-vis Durgā* arose out of the year beginning with *Kanyārāśi. The* temple at *Kanyākumāri* is remniscent of the prehistoric epoch of *Tāntric* astronomy.

(b) Legend of *Hari-Hara-putra* : The zodical characters are : Śāstā is the summer solstice conceived as the son of *Dhanu* rāśi (Hara) and Leo rāśi *(Hari)*. In 4137 BC with the autumnal equinox at the beginning of *Dhanu* (240^0), Summer solstice had began its anticlockwise sojourn in Leo rāśi at 150^0 after crossing *Kanyā*. According to mythology Śāstā is *Pulivāhana* (riding over *Siṃha*) and averse to women (already crossed over *Kanyā). Hari* is son of *Siṃha* Śāstā who becomes *Mohinī* at 150^0 i.e. beginning of *Kanyā*. From *Mūlādhāra* (240^0) to *Aśvinyādi* (0^0) - singifying the "*Śīrṣa-padmam*", there are 18 *nakṣatras* which symbolise the 18 steps of *Yogavidyā*. We can find a reflection of this in Śabarimala where Deity is "*Yogārūḍha*" and sits over 18 steps.

(c) Serpent worship of Kerala

Serpent worship of Kerala also had its origin in the Tantric epoch of 4137 BC. *Rāhu* and *Śikhi*, the nodes of Moon fell over the signs *Dhanu* and *Mithuna* and thus Rudra became the serpent-bearer while *Kālacakra* got the new name *Rāhu-Śikhi-cakra* or Rāśi-*cakra* in short. *Rātu* and Śikhi also thus received the name "*Kālasarpa*" (Serpent of Time). Thus worship of the *Liṅga*, *Sarpa*, *Kanyā*, *Śāsthya*, all had its origin thus in the *Tāntric* astronomy of 4137 BC and its remnants are still visible in Kerala. It must be specially noted here that the deity Nāgarāja *or the Serpent God of Maṇṇāraśāla, in* fact, Śiva-liṅga

adorned with the Serpent and is reflective of the astronomical tradition that began in 4137 BC.

It is apparent from the above that the sidereal nature of the Siddhāntic zodiac and Āryabhaṭa's astronomy had its origin in the *Tāntric* school of astronomy that prevailed probably in its decadent form.

Place of Āryabhaṭa

The above-mentioned relics of the *Tāntric* part and a prehistoric school of astronomy explain the emergence of the Kerala tradition in Hindu astronomy. Without the fertile grounds of Kerala, it was impossible for the Greek theory to take root in India. Āryabhaṭa, possibly a native of Kerala who incorporated the Hipparchian/Ptolemaic notion of vernal equinox as the zero point into the traditional astronomy of Kerala. Kerala was probably the home of Indian astronomy in those days and hence the Āryabhaṭan astronomy had its spread to distant places such as Kusumapura, Vallabhi (Bhāskara I) etc.

Conclusions

Āryabhaṭīya depicts an anomalous zodiac incompatible with its own assumption of a stationary Aphelion. As such, the solar year has no physical meaning and it is an arbitrary value that bridges the epoch K_0 with the vernal equinox of K_{3623} (AD 522). The original *Svāyaṃbhūva-siddhānta* on which Āryabhaṭa based his work probably made use of the anomalistic solar year and an appropriate correction to keep the sidereal zero point fixed. The stationary aphelion that we see in *Āryabhaṭīya* suggests that the original zero point had vernal equinox over it in AD 238 or K_{3339}. This in turn suggests, Mūla as the fiducial star of fixed sideral longitude 240^0. Hindu mythology renders the identification of Rudra as Mūla nakṣatra. Legends of Kerala about Kanyākumāri and Śabarimala temples provide indirect substantiation to the original epoch of Mūlādhāra *Rāhu-Śikhi-Cakra* in 4137 BC. Kerala appears to be the original seat of a Tantric cult and a school of sidereal astronomy which developed the disciplines of Yoga and Jyotiṣa.

Appendix-I

Original Epoch of Indian *Siddhāntic Astronomy*

The following astronomical data is substantiative of the analysis given earlier:

Epoch : *21 March 231AD, Monday 17 33 UT (22 36 Ujjain LMT)*
JD: 1805510.231

Mūla (Lambda Scorpii) precisely had a longitude of 239° 58′ = 240° from the vernal equinox.

New moon took place on Monday at 1046UT or 1549 (Ujjain LMT) for JD=1805509.866 - midnight of 21/22 March, Monday coinciding with the S'ukla-1 marked the beginning of Caitra at Ujjain. The epochs K_0 and K_{3332} were as shown below at Ujjain:

K_0	K_{3332}
JD: 588465.2104	1805510.2104
UT:17/18 Feb. 3102BC Thursday Midnight	21/22 March 231 AD Monday Midnight
Mean Sun 301° 36′	358° 05′
Solar anomaly 105° 38′	105° 26′
Mean Moon 297° 11′	7° 26′
True Sun 303° 34′	00° 03′ 47"
True Moon 315° 37′	03° 17′

$K_{3332} - K_0 = 1217045$ days $= 3332 \times 365.2596038$
i.e. 3332 anomalistic years separated the two epochs.

Discussion

(a) Āryabhaṭa's choice of Wednesday Sunrise as Yugādi is untenable as the mean new moon was on Thursday night. This wrong choice was a consequence of the modification of the epoch from AD 231 to AD 522 during which the vernal equinox got shifted by four degrees. To account for this shift Āryabhaṭa reduced the year length by 9.232 X 10E-04 days (which accumulated to 3.345 days in 3623 years) and shifted the Yugādi by –0.75 days from Thursday midnight to Wednesday Sunrise.

(b) Varāhamihira chose JD=1905588.263 as his epoch and this very nearly marked the mean equinox of AD 505. 3606 years of 365.25875 days on counting back, took him to the midnight of Thursday rather than Wednesday sunrise of Āryabhaṭa at Yugādi. According to modern computation the new moon corresponded to 21 March 505 AD 19 55 (Ujjain LMT) (JD=1905589.12) with the Sun having a true longitude of $2^0 32'$.

True equinox was on 19 March 505 AD at 05 47 (Ujjain LMT) with JD=1905586.528. True Moon was $329^0 08'$.

It is apparent from the above that the astronomical phenomenon of AD 231 only is compatible with the assumption of a mean new moon at Yugādi on Thursday midnight. Varāhamihira stuck to the tradition as far as Yugādi is concerned but his epoch of AD 505 is only computational, *i.e.* the mean equinox coinciding with a mean new moon and hence the epoch can not be taken as observational as in AD 231 where the spring equinox and Śukla-1 coincided almost perfectly.

The spring equinox of AD 231 having the same anomaly as the Sun of K_0 and coinciding with Caitra-S'ukla-1 precisely over the point 120^0 east of Mūla renders irrefutable evidence towards the theory of *Mūlādhāra* Rāhu-Śikhi Cakra.

Note : The length of the sidereal year in 231AD was 365.2563586 days. The anomalistic year of 365.2596038 therefore meant an eastward regression of 11".5 for the initial point and this accumulates to 10^0 39′ in 3332 years. This in fact is the 'deviation' of Sun relative to the "zero point with Mūla as fiducial" at K_0.This explains the choice of K_0 as Yugādi and the concept undoubtedly belongs to the Pre-Āryabhaṭa period. An exhaustive discussion on the intricacy of the Siddhāntic solar years is available at reference[7].

In discarding the earlier epoch of AD 231 and the anomalisic solar year whether Āryabhaṭa did the right thing or not must be contemplated in detail.

References

1. K. S. Shukla and K. V. Sarma, *Āryabhaṭīya*, Critically edited with Translation and notes, Indian National Science Academy New Delhi-2, 1976.
2. *Indian Journal of History of Science* (IJHS) 12.2(1977).
3. *Āryabhaṭīya* IV.50, See (1) above, p. 164.
4. T. S. Kuppanna Sastry, 'The School of Āryabhaṭa and the peculiarities thereof" IJHS, 4.1-2(1969)126-134.
5. K. V. Sarma, 'Tradition of *Āryabhaṭīya* in Kerala" IJHS 12.2 (1977) 194-199.
6. Rev. E. Burgess, *Sūryasiddhānta*, English translation, 1859-60.
7. For a detailed discussion see : K. Chandra Hari "Intricacy of the Siddhāntic Solar year", IJHS, 34.2(1999).
8. S.B. Dikshit, *Bhāratīya Jyotihśāstra*, vol. II, pp. 206-207 and p. 139 of ref. (7) above.

9. K. Chandra Hari "On the Origin of Kaliyugādi Synodic Super-conjunction", IJHS 33.3(1998), 193-201.

10. K. Chandra Hari, 'Ancient Indian versus Babylonian Astronomy,' under Publication.

11. For a brief discussion see : K. Chandra Hari, "On the Origin of Sidereal Zodiac and Astronomy", IJHS. 33.4 (1998) 257-266.

12. See ref. 10 above.