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DATE OF HARIDATTA, PROMULGATOR OF THE PARAHITA SYSTEM OF ASTRONOMY IN KERALA

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The present paper is an attempt to fix the date of Haridatta, one of the pioneers of the Kerala school of Hindu astronomy. Only one of his treatises *viz., Grahacāranibandhanam*, could be located so far and it offers no clues as regards his date. Legends associate him with the popular *Vāgbhāva* correction, which was introduced in AD 684 or Kali year 3785. Another work, *Grahacāranibandhana-saṅgraha* was found to bear the *Kalidina* 1472723, which corresponds to AD 931. An attempt is made here to study these two dates with the help of modern astronomy.

Key words : Haridatta, *Āryabhatīya, Vāghbhāva.*

INTRODUCTION

Kerala, the tiny tract of land lying between the Western Ghats and the Arabian Sea had kept alive a distinct astronomical tradition since very early times. Among the early tracts of this tradition are the *candravākyas* (moon sentences, commencing with, *gir naḥ śreyaḥ* of a legendary). Among Varauci's 12 sons, the eldest, Melattol Agnihotri is believed to have been born on 18 February 343 AD, corresponding to the Kali - chronogram 1257921. This is supportive of the belief that Vararuci belonged to the 4th century AD. Apart from the underlying astronomical theory of Kerala astronomers the technique derives its elegance from the ingenious use of the Kaṭapayādi notation to represent the cumulative longitudinal arcs of the planets. As may be gleaned from the process, the technique, which relied upon the "horizon phenomena" had its origin and evolution before the advent of the theory of the epicycles, that is, before the revolution spearheaded by Āryabhaṭa in the 6th century AD.

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Though Āryabhaṭa does not belong to Kerala, the Kerala tradition of Āryabhaṭan astronomy vouchsafes the fact that it was Kerala that offered the richest soil for it development. Despite this geographical disadvantage, the Āryabhaṭan School had its bloom in Kerala in the centuries that followed Āryabhaṭa in successive steps among which a few might be mentioned :

- AD 684–*Parahita-gaṇitaṃ*, introduction at Tirunāvāya
- AD 860–Śaṅkaranārāyaṇa, *Golayantra* at Mahodayapura
- AD 932–*Parahita* resume: *Grahacāranibandhana saṅgraha*
- AD 1431–*Dṛggaṇitam* by Parameśvara
- AD 1500–*Tantrasaṅgraha* of Nīlkaṇṭha Somayāji
- AD 1600–*Rāśigolasphuṭāniti* (containing reduction to the ecliptic): by Acyuta Piṣāroṭi

Major Kerala authors and their works remain almost untouched by modern historians of science except the publication of these texts with translation and notes by Dr. K.V. Sarma. The present paper is an attempt to throw some light on one among them, Haridatta, one of the pioneers of Kerala astronomical tradition, who is the enunciator of *Parahita-gaṇitam* at the epoch AD 683 or K_{3784}.

Āryabhaṭa Tradition in Kerala

The Kerala tradition places the epoch of *Āryabhaṭīya* at Kali year 3623 (elapsed)[1], corresponding to an *ahargaṇa* of 1323332.19981 days, which, according to modern reckonings, is Monday 21 March 522 AD 12 *ghaṭis* after the sunrise of Ujjain or 10:48 LMT. The Julian date as per the terrestrial dynamic time reckoning employed in astronomical computations will be 1911797.79124. The Kaliyugādi Epoch (K_0) shall be JD [TDT] = 588465.59958. Siddhāntic astronomy rested upon the planetary motions based on an assumed synodic super-conjunction at the zero point of the zodiac for the epoch K_0 and whatever deviation had been there for the planets from zero in turn caused a cumulative error in the period that followed the epoch of an astronomical treatise. The K_0 assumption in fact had its positive and negative sides. The positive side was that the assumption enabled the derivation of theoretical synodic periods, which were more precise than those could be observationally determined in those days. But still those theoretical synodic periods and the respective planetary velocities were not exact like the modern values and hence the system of Siddhāntic astronomy worked very accurate only in the vicinity of an epoch fixed duly through careful observations. Astronomical treatises as such were in need of continuous revision with the passage of time and in this context we can find the following remarkable opinion of Nīlakaṇṭha in his work *Jyotirmīmāṃsā*[2]:

"*Āryabhaṭīyasya ca parīkṣāparatvādeva sakaladeśakālayoḥ sphuṭārthatvaṃ taduktabhagaṇādivaiśiṣṭyāt / ata idameva parīkṣāsūtraṃ siddhāntarebhyo asya gauravamāpādayati /...*"

"It is the direction for observation and verification that makes *Āryabhaṭīya* universally and eternally valid rather than the planetary revolutions stated. Emphasis upon observational verification alone has made *Āryabhaṭīya* superior to other Siddhāntas..."

The successive revision of the planetary revolutions of a Mahāyuga in the Siddhāntic tradition therefore had a genetic connection with the planetary positions at the beginning of Kaliyuga, which were as follows:

Table 1. Yugādi Positions of Planets; 18.02.3102 BC, 06:00 LMT of Ujjain: JD [TDT] = 588465.45

Planets	Modern λ	Sidereal[3] value	Deviation From 0°	Revolutions: *Arybhaṭīya*	Equivalent Modern value	Cum. Error[4]:
1	2	3	4	5	6	7
Sun	304°55'01"	352°51'59"	-7°.13374	4320000	4320027.41754	-8.278
Moon	320°02'20"	05°06'06"	5°.10194	57753336	57753350.762	-4.457
Mars	301°19'30"	340°38'48"	-19°.3532	2296824	2296890.513	-20.081
Mercury	290°20'48"	323°38'53"	-36°.3521	17937020	17937147.27	-38.425
Jupiter	317°39'26"	08°09'24"	+8°.15657	364224	364197.3656	8.041
Venus	317°43'37"	264°6'12"	+26°.77	7022388	7022304.772	25.128
Saturn	276°41'34"	332°07'25"	-27°.8764	146564	146657.1028	-28.109

A comparison of column-4 with column-7 is illustrative of the genetic connection of Āryabhaṭa's planetary revolutions with the actual mean positions of Planets at K_0. The exactness of the computations depended on the *dhruvas* or epochal positions of the treatise and with the passage of time the inaccuracy of the planetary motions contributed a cumulative error.

Epochal Positions of Āryabhaṭīya

The *Āryabhaṭīya* as such does not make an explicit mention of any epochal planetary positions. As indicated above the Kerala tradition accepts the Kali year *"girituṅga"* or Kali,3623 [elapsed] as the epoch of *Āryabhaṭīya* and accordingly the epochal mean longitudes as per the treatise can be computed and compared with the results of modern astronomical algorithms:

Table 2. Epoch of *Āryabhaṭīya*: $K_{3623,}$ 21st March 522 AD Monday 12 *ghaṭis* after sunrise: 1048 LMT-Ujjain JD [TDT] = 1911797.79123727

Planet	Mean λ *Āryabhaṭīya*	Mean λ Modern	Difference Col.2-Col 3
1	2	3	4
Sun	0°	0°07'15"	-7'
Moon	94°41'39"	95°02'11"	-20'
Mars	89°26'46"	89°36'14"	-10'
Mercury	05°17'18"	03°13'11"	+2°4'
Jupiter	165°17'46"	165°31'5"	-13'
Venus	135°58'37"	135°58'26"	0
Saturn	330°06'52"	329°47'25"	+19'
Node	87°06'	87°08'9"	-2'
Moon-apogee	251°27'11"	251°24'	+3'

If we leave Mercury aside the average error in the six other longitudes is less than 12 minutes [1500 years ago] when compared with modern longitudes derived from 3rd degree polynomials of time. Āryabhaṭa's accurate epochal positions and the erroneous zero mean longitudes of K_0 could be bridged only by erroneous sidereal periods/planetary motions and as such the computations were bound to be in error with the passage of time. As can be noted in Column 4 of Table 1, the planets having a negative deviation had a gain of longitude by the zero assumption and hence a slower motion in the period since K_0 while the planets which were ahead of zero had to cover so much extra and hence a faster motion in the Siddhāntic frame as compared to the modern true values. In the period that followed Āryabhaṭa's epoch accuracy of the *Karaṇa* computation in astronomical manuals rested upon the approach of the sidereal periods to their true values. As the slower planets had a decreased number of revolutions their number of revolutions had to undergo an increase in the subsequent revisions while the faster ones had to be of a decreased number of revolutions to be in tune with the *Karaṇa* periods.

As recorded in the *Sadratnamālā* and *Dṛkkaraṇa*, the first of the revisions to *Āryabhaṭīya* took place in K_{3785} or AD 684 and the modification was known as *Parahita-gaṇita*. No manuscript could yet be traced which contain the modified parameters and as noted by K.V. Sarma and T.S.K. Sastri[5] the supposedly Parahita manual, *Grahacāranibandhana* of Haridatta contains only the parameters of Āryabhaṭa. But Haridatta himself has referred to (III. 44) to a larger work of his *'Mahāmārganibandhana'*, which is yet to be dis-covered. We shall discuss below the "Vāghbhāva correction, called also *Śakābda* or *Bhaṭābda* correction to be applied for obtaining the true positions of planets, taking Śaka 444 denoted by the numeral *bha-va-bhā* in Kaṭapayā di system.

GRAHACĀRANIBANDHANA OF HARIDATTA

The *Grahacāranibandhana* of Haridatta is the basic Karaṇa text of the popular "Parahita" system of astronomy, which had been in oblivion till K.V. Sarma could locate five manuscripts of it, edit and publish it in 1954. In Sarma's words[6]:

"Scholars have hitherto understood by *Parahita* only the system current under that name and nothing seems to have been known of *Grahacāranibandhana*, the basic text of that system, or its author Haridatta. It is generally presumed that the system was inaugurated by Kerala astronomers at Tirunāvāya on the occasion of the twelve-yearly Māmāṅkam festival held at that place, when they felt the need to correct the results arrived at through the *Āryabhaṭīya*."

The date of the *Grahacāranibandhana-saṅgraha* edited on the basis of two independent manuscripts and added to this edition as an Appendix, bears the *khaṇḍas* or cut to dates, *gorasaṃ rasavarya* (14, 72, 723), which works out to be 932 AD[7].

"The numerous Karaṇa texts of Kerala in Malayalam and in Sanskrit, which incorporate bodily the tabular equations and constants of *Grahacāranibandhana* do so without making mention of their source. It would seem, though it is somewhat strange, that the more the system grew popular, the more the author was pushed in to oblivion".

"The Parahita system of astronomical computation is based on the *Āryabhaṭīya* and has the widest vogue in Kerala, from where it spread to the Tamil area...Both Malayalam and Sanskrit astronomical works of Kerala affirm that the *Parahita* system was introduced in Kali 3785, corresponding to AD 683..."

In fact the treatise proper does not give the specific epoch. But verses 47-49 of the third as well as last chapter gives the *"saptamayuga-dhruvas"* which corresponded to the *Kalidina* of 210389 × 6 = 1262334 and epoch K_{3456}. Also the verses 16-18 have provided the planetary mean motions as per *Āryabhaṭīya* for the period of 576 years or the Yuga of *"dhījagannūpura"* (210389) days. The data is summarized in the following Table 3:

Table 3. *Dhruvas* and Mean Motions given by Haridatta

Planets	*Dhruva* for 7th Yuga	Modern astronomical Values	Mean motion for 576 years *Āryabhaṭīya*	Mean Longitude K_{4032}	*Ayanāṃśa* Corrected Values	Modern Astronomical Values
1	2	3	4	5	6	7
Moon	240·768	238·7232	160·128	40·896	47·71267	46·9044
Mars	165·312	162·236	87·552	252·864	259·6807	260·94325
Mercury	221·76	215·670	216·9606	78·72056	85·53722	86·4583
Jupiter	136·512	134·7833	202·752	339·264	346·0807	344·2661
Venus	327·744	326·6082	114·624	82·368	89·18467	85·16232
Saturn	90·432	86·506	195·072	285·504	292·3207	294·01417
Apogee	207·0803	295·467	34·512	241·5923	248·409*	335·10712
Rahu	281·088	257·324	346·848	267·936	274·7527	276·1211

**Dhruva* of 90° to be added: So Apogee = 338.409: *Ayanāṃśa* = 06°49'

Column 2: verses 47-49 and Column 4: Verses 16-18 of *Grahacāranibandhana*

Beginning of the 7^{th} Yuga: *Kalidina* = 1262334: 20 March 355 AD, Monday: 06:00 Ujjain-LMT. JD [TDT] = 1850799.60844. K_{4032}: *Kalidina* = 1472723: Friday, 25 March 931 AD: 06:00 Ujjain-LMT. JD [TDT] = 2061188.56179.

The *Grahacāranibandhana-saṅgraha*, gives *dhruva* for the *dinakhaṇḍa* of 1472723, which is 4032 × 365.2586806, suggests the epoch as Kali-year 4032 (elapsed)[8]. What then may be the basis of the tradition that places the introduction of Parahita to AD 684 or K_{3785} — almost 250 years earlier ? We shall look for an answer to this question in the following discussion.

Epoch vis-á-vis Kalikhaṇḍa of 14,72,723

The *Kalikhaṇḍa* of 1472723 days arose out of the shorter yuga of *"dhī-ja-gannū-pu-ra"* = 210389 days or 576 years used in the treatise and as such the epoch K_{4032} is based on the rationale of an integral number of shorter yugas of 576 years, *i.e.*, 4032 = 576 × 7 or *Kalikhaṇḍa* 1472723 = 210389 × 7. The *Grahacāranibandhana-saṅgraha* as such undoubtedly belongs to the epoch K_{4032}. This cannot be the date of Haridatta, because he has given the *dhruva* for the beginning and end of the 7^{th} Yuga that prevailed from Kali-year 3456 to 4032, exclusively based on *Āryabhaṭīya*. As can be seen from column 6 of Table-3 given above the *dhruva* given for both K_{3456} and K_{4032} have much deviation from the corresponding modern values and can therefore be inferred as not observational – only a theoretical derivation based on *Āryabhaṭīya*. A very pertinent question arises now: What then is the distinctive contribution of Haridatta for which the tradition had been paying obeisance to him ?

Śakābda or Bhaṭābda saṃskara (*vāghbhāva-saṃskāra*)

As is well known, Haridatta is the principal author of the Kerala tradition that takes Kali year 3623 or Śaka 444 as the epoch of *Āryabhaṭīya* on the basis of the interpretation of the verse 10 of the Kālakriyāpāda:

ṣaṣṭyabdānāṃ ṣaṣṭiryadā vyatītāstrayaśca yugāpādāḥ /
tryadhikā viṃśatirabdās tadeha mama janmanotītāḥ //

On the Haridatta's interpretation of this verse the following information is available in the *Āryabhaṭīya* translated by K.S. Shukla and K.V. Sarma:

"The Kerala astronomer Haridatta (c. AD 683), the alleged author of the *Śakābda* correction has, as remarked by Nīlakaṇṭha in his commentary on the *Āryabhaṭīya* (rather in surprise), interpreted the above stanza in a different way, *viz*,: "When sixty times sixty years and three quarter yugas had elapsed, twenty three years of my age have passed since then".

This means that Āryabhaṭa was born in Śaka 421 and wrote the *Āryabhaṭīya* in Śaka 444. But no commentator of the *Āryabhaṭīya* has interpreted the above stanza in this way, and T.S. Kuppanna Sastri has rightly called it a "wrong interpretation". Another Kerala astronomer (probably Jyeṣṭhadeva), the author of the *Dṛkkaraṇa* (AD 1608), an astronomical manual in Malayalam, has actually stated that Āryabhaṭa was born in Śaka 421 and that he wrote the *Āryabhaṭīya* in Śaka 444. This is according to T.S. Kuppanna Sastri, a mistaken impression..."

Without entering into the controversy of the literary interpretation, it may be noted that the vernal equinox coincided perfectly with the Sun of *Āryabhaṭīya* for K_{3623} rather than K_{3600}—where we can find the Sun off by 17 minutes of arc. Haridatta as well as those who followed him like Mañjula, the first astronomer who has spoken explicitly of the *ayanāṃśa*, as such had ample justification for considering Kali 3623 as the zero year. Origin of this tradition and the incorporation of *ayanāṃśa* into the *Āryabhaṭīya*-based astronomy certainly took place after the times of Bhāskara-I, who lived in the first half of the 7th century AD. As regards the *Bhaṭābda-saṃskāra*, Sarma has provided the following details:

"The distinctive contribution of Haridatta, apart from his resolving the *Āryabhaṭīya* calculations and using the *Kaṭapayādi* system of numerals, is the correction he introduced for the values of the mean and true positions, the velocity etc., of the moon and other planets as obtained from Āryabhaṭa's constants. This correction is called *Śakābda-saṃskāra* since it applied from the date of Āryabhaṭa in the Śaka era, *viz*., 444 (*Vāghbhāva, vibhava, bhavabhānu*), at which date his constants gave accurate results... The above *saṃskāra* states that for every completed year after Śaka 444 (Kali 3623), a correction in *kalās* (minutes) of (-)9/85, 65/134, 13/32, (+)45/235, (+)420/235, 47/235, 153/235 and (+) 20/235 should be made to the mean positions of the Moon, its apsis and Node, Mars, Mercury, Jupiter, Venus and Saturn respectively and that no correction need be made in the case of the Sun".

The impact of these corrections considered over the Mahāyuga interval of 4320000 years is reflected in the integral number of revolutions given in Table-6, column-3. K.S. Shukla and K.V. Sarma have given the corrections by Lalla from K_{3600} and a variant of the above correction as available in *Grahacāranibandhana-saṅgraha* in their *Āryabhaṭīya* translation. These corrections obviously mean that the Āryabhaṭa's mean motions became incorrect in the immediate vicinity of his epoch due to the genetic connection it had with the Yugādi errors in the zero assumption and also precession had to be accounted for in the period since K_{3623}. It becomes apparent from a moment's reflection that the corrections would have been meaningless in the absence of *ayanāṃśa* at the rate of 1 minute per year as accepted in the Kerala tradition. See below for example the *Parahita dhruvas* given in *Grahacāranibandhana-saṅgraha* for *Kalikhaṇḍa* of 1472723.

Graha-Madhyamas versus Modern Mean Longitudes[9] for *Kalidina* 1472723

In the following Table, the *Khaṇḍadhruvas* of 1472723 days available in the *saṃgraha* is contrasted with *vāghbhāva*—corrected *dhruvas* for the date and the respective modern astronomical mean longitudes. The *Khaṇḍadhruvas* given in column-2 are exclusively based on *Āryabhaṭīya* and do not carry any signature of Haridatta or the legendary *Vāghbhāva* corrections.

Table 4. Epoch of *Grahacāranibandhana-saṅgraha*
Friday, March 25 931 AD sunrise-Ujjain JD [TDT] = 2061188.56178968

Planet	*Parahita / Āryabhaṭa*	*Parahita + Ayanāṃśa* (06°49')	*Vaghbhāva: Ayanāṃśa* = 06°46'	Modern mean λ	Difference Col. 4-Col. 5
1	2	3	4	5	6
Sun	00°00'	06°49'	06°49'	06°42'27"	+7'
Moon	40°54'	47°43'	46°58'11"	46°54'16"	+4'
Mars	252°52'	259°41'	260°59'10"	260°56'17"	+3'
Mercury	78°43'	85°32'	97°44'19"	86°27'30"	+11°
Jupiter	339°16'	346°05'	344°43'02"	344°15'58"	+28'
Venus	82°22'	89°11'	84°44'49"	85°09'44"	-25'
Saturn	285°30'	292°19'	292°54'	294°00'51"	-66'
Node	267°56'	274°45'	277°31'25"	278°07'16"	+36'
Apogee-Moon	331°35'	338°24'	335°06'54"	335°06'26"	0'

It is apparent that without *ayanāṃśa* and the *Vāghbhāva* corrections satisfactory agreement could not have been possible between observations and computation.

Actual Epoch of Haridatta

As mentioned earlier Haridatta has given the *dhruvas* for K_{3456} as well as the mean motions over 576 years, which means the theoretical positions for K_{4032}. We know through references in the traditional astronomical literature of Kerala that Haridatta's algorithms came into force after the *Māmānkaṃ* festival for K_{3785} which both K.S. Shukla and K.V. Sarma have taken consistently as AD 683. The year AD 683 actually corresponds to K_{3784} (elapsed) and so K_{3785} (elapsed) must be AD 684. It is apparent that for some reasons known to them they have adopted the Kali year 3785 as current and hence the mention of AD 683 as the epoch of Haridatta. As the present author is unable to resolve the matter, the impact of *Vāghbhāva* corrections and *ayanāṃśa* for AD 683 and 684 are provided below :

Table 5. Mean Longitudes for K_{3784} (elapsed) or K_{3785} (current) Monday, 22nd March 683 AD, 50^{ghatis} 51^{vighatis} after sunrise of Ujjain JD [TDT] = 1970604.42511023

Planet	Āryabhata error K_{3623} to K_{3724}	*Vāgbhāva* error K_{3623} to K_{3784}	Mean λ *Āryabhaṭīya* K_{3784}	*Vagbhāva* Corrected Mean λ	Column 5 + *ayanāṃśa* [2°41']	Mean λ Modern	Error
1	2	3	4	5	6	7	8
Moon	-12'	-29'	231°57'7"	231°39'35"	234°20'35"	234°37'22"	-17'
Mars	-54'	-23'	305°10'5"	305°40'55"	308°21'55"	308°33'24"	-12'
Merc.	-102	186'	180°18'24"	185°06'35"	187°47'35"	182°59'8"	+287'
Jupiter	+21'	-11'	11°58'5"	11°25'53"	14°06'53"	14°05'17"	+1'
Venus	+67'	-38'	33°0'58"	31°16'9"	33°57'9"	34°26'48"	+31'
Saturn	-75'	-61'	136°30'53"	136°44'34"	139°25'34"	139°40'23"	-15'
Node	-35'	+30'	211°24'5"	210°18'19"	212°59'19"	213°00'44"	-1'
Apsis-Moon	-	-	321°43'29"	320°25'53"	323°06'53"	323°07'07"	-1'

Exactness of Jupiter, Moon's apogee and Node are especially noteworthy at this epoch.

Table 6. Mean Longitudes for K_{3785} (elapsed) : 22nd March 684 AD, 03:30 UT Tuesday, 06gh 22vigh after sunrise at Ujjain: JD [TDT] = 1970969.68371384.

Planet	Mean λ *Āryabhaṭīya* K_{3785}	*Vagbhāva* Corrected Mean λ	Column 5 + *ayanāṃśa* [2°41']	Mean λ Modern	Error	Error in Previous Year
1	4	5	6	7	8	9
Moon	357°51'14"	04°26'09"	07°08'09"	07°24'32"	-16'	-17'
Mars	136°34'12"	137°05'14"	139°47'14"	139°52'04"	-5'	-12'
Mercury	235°03'30"	239°53'43"	242°35'43"	236°53'58"	+222'	+287'
Jupiter	42°19'12"	41°46'48"	44°28'48"	44°26'03"	+2'	+1'
Venus	258°12'54"	256°27'26"	259°09'26"	259°18'55"	-9'	+31'
Saturn	148°43'42"	148°57'29"	151°39'29"	151°54'05"	-15'	-15'
Node	192°02'57"	190°57'06"	193°39'06"	193°40'12"	-1'	-1'
Apogee-Moon	02°24'35"	01°05'55"	03°47'55"	03°48'44"	-1'	-1'

The error as compared to modern mean longitudes is a minimum for K_{3785} (elapsed) as compared to K_{3785} (current). It is therefore more likely that the "*Vāgbhāva*" corrections might have its introduction by Haridatta in Kali year 3785 (elapsed). The extreme accuracy of the mean longitudes corrected for precession since K_{3623} or AD 522 is especially noteworthy. This concordance suggests the meaninglessness of *Vāghbhāva* corrections or any other corrections in the absence of *aynāmamśa* and hence the legendary epoch of K_{3785} in the post-Bhāskara-I period may be the epoch at which *aynāmamśa* got incorporated into the Āryabhaṭan astronomy of Kerala. The Parahita *dhruva* (mean longitudes) as per *Grahacāranibandhana-sañgraha* are the same as that derived from *Āryabhaṭīya*. It becomes therefore apparent that Parahita never adopted a modification of the revolutions of *Āryabhaṭīya*, as it would have meant a change in the epochal values of K_{3623}. Karanādi computation was effected by applying the *Vāghbhāva* corrections to the years elapsed since K_{3623} of Śaka 444 rather than applying the revolutions from K_0. It is apparent from Tables 3 & 4 that the *Vāghbhāva* corrections were more suited to the epoch K_{3785}—the legendary Parahita epoch of K_{3785} rather than K_{4032} [*Kalidina* = 1472723], which we find in the *Grahacāranibandhana-sañgraha*. Perhaps, the *Grahacāranibandhana-sañgraha* and depicting the *Kalidina* = 1472723 may be a later work by some anonymous author of K_{4032} epoch. It much be specially noted that the Parahita *dhruva* of the said *sangraha* is a derivation exclusively based on *Āryabhaṭīya* and as such of serious error in K_{4032}.

IMPACT OF "VĀGHBHĀVA" CORRECTED (HARIDATTA) REVOLUTIONS

Table 7. Numbers of Revolutions vis-a-vis epochal errors

Planet	Revolutions		Cumulative deviation from Modern* during 409 years: K_{3623}-K_{4032}		Āryabhaṭan Error in	Haridatta Error in	
	Āryabhaṭīya	Haridatta	*Āryabhaṭīya*	Haridatta	K_{3623}	K_{4032}	K_{3784}
Moon	57753336	57753314.200	-30'	-75'	-20'	+13'	-17'
Mars	2296824	2296862.3	-136'	-58'	-10'	+2'	-12'
Mercury	17937020	17937378	-260'	+472'	+124'	+660'	+287'
Jupiter	364224	364184	+54'	-28'	-13'	+28'	+1'
Venus	7022388	7022257.8	+170'	-96'	0	+25'	+31'
Saturn	146564	146581	-190'	-156'	+19'	-66'	-15'

*Revolution numbers derived from modern astronomical data is given in Table-1

At K_{4032} Jupiter, Saturn, Mercury and the Moon's Node have serious errors as compared to the same at epoch K_{3784}. But it is apparent that in the period since K_{3623} the "*Vāghbhāva*" correction could yield relatively error-free computations for more than 200 years between K_{3784} to K_{4032} or even up to the date of Parameśvara (K_{4532}), who authored *Dṛgganita* to replace the *Parahita-gaṇita* that had become obsolete by that time, "*Vāghbhāva*" corrections could accomplish this task as the resultant mean motions were more accurate, *i.e.*, closer to modern values than those of *Āryabhaṭīya*.

Table 8. Mean Motions of Planets.

Planet	*Āryabhaṭīya*	Mean Motions	
		Vāghbhāva	Modern astronomy
Moon	27.3216685	27.3216788	27.3216615
Mars	686.9997440	686.9882883	686.97985
Mercury	87.9698802	87.9681244	87.969256
Jupiter	4332.2721732	4332.7480065	4332.5889
Venus	224.6981369	224.7023030	224.70080
Saturn	10766.0646543	10764.8160403	10759.23
Moon's Node	6794.7495113	6792.3715699	6793.469
Apogee-Moon	3231.9870796	3232.6253691	3232.58853

Except for Moon and Mercury, all *Vāghbhāva* corrected planets had motions closer to modern values. As can be seen in Table 1, the genetic connection of mean motions to K_0 errors had been over at K_{3623} and as such in the subsequent period the observations should have led to correct mean motions.

Conclusions

It is apparent from the data furnished above that Haridatta could achieve an accuracy surpassing that of Āryabhaṭa for his epoch as well as the successive years. The *Karaṇa* he had created based on the *Yuga* of *Dhijagannūpra* had reigned supreme in the Kerala and Tamil areas for more than a millennium. The *Vāghbhāva* correction and *ayanāṃsa* based on K_{3623} of Śaka 444 have played a crucial role in maintaining the accuracy of computations since the 6th century AD. The exactness of *Vāghbhāva* corrected longitudes with modern values for the epoch of AD 684 associated with Haridatta is substantiative of the date of Haridatta as AD 684. The ingenuity of Haridatta is evident from the conception of the shorter yuga of 210389 days, which is 1/7500th part of the Mahayuga of 4320000 years. Also, Haridatta is the only astronomer of the post-Āryabhaṭan period who had conceived an astronomical epoch, which dates back of K_{3456} or AD 355—150 years before Āryabhaṭa himself.

References

1. *Sadratnamālā* of Śaṅkara Varman, Ed. K.V. Sarma, Indian National Science Academy, New Delhi, 2001 and *Dṛkkaraṇa*, Pariccheda 1.

2. *Indian Astronomy-A Source Book*, Eds. B.V. Subbarayappa and K.V. Sarma. p. 143. Nehru Center, Bombay.

3. Sidereal values have been computed with reference to the equinox of AD 522: *Ayanāṃśa* for K_0 as such amounts to (+) 49°55'6".

4. Column-7 has been computed on the basis of the deviation of Āryabhaṭa's revolutions from the modern values.

5. *Vākyakaraṇa,* Introduction. Critically edited with a resume in English by TSK Sastry and KV Sarma, Kuppuswami Sastri Research Institute, Madras, 1962.

6. *Grahacāranibandhana* of Haridata, Ed. K.V. Sarma. K.S.R. Institute, Madras, 1954. Also, see *Contributions to the Study of the Kerala School of Hindu Astronomy and Mathematics,* Vol. 2: K.V. Sarma, p. 1009.

7. Actually the *Kalikhaṇḍa* of 1472723 falls in 1931 AD as shown below.

8. In the following part we shall use the notation K subscript the 'year elapsed' to represent the Kali-years. Example: K_{4032} represents the Kali-year 4032 (elapsed).

9. Strictly speaking, the modern mean longitudes and the siddhāntic *madhyamaṃś* are not entirely the same even if the precession is accounted for. True positions decremented by the equation of center formed the siddhantic *madhyamaś* while in modern astronomy the mean positions are arrived at after scores of other corrections which represent the perturbations to the mean orbit. Obviously equality cannot be looked for while comparing the epochal mean co-ordinates. But even then the contrast, siddhāntic versus modern, of the different epochs have been employed by earlier scholars to gain a prima facie understanding of the merits of the siddhāntic works.