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INTRICACY OF THE SIDDHĀNTIC SOLAR YEAR

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The solar year length of the Siddhāntic astronomy is extra-long as compared to the sidereal and tropical year that had been in use elsewhere in the world, and is yet to receive a satisfactory explanation. The present paper is an attempt to have an analytic look at the complicated situation presented by the Siddhāntic year length of 365.25875 days vis-a-vis the generally accepted zero point of the Siddhāntic zodiac viz., the vernal equinox of Kali 3600 (elapsed). The Hindu solar year is shown to be "anomalistic" in origin and the decrement of the siddhāntic value as compared to the true anomalistic year is explained as due to the departure of the Siddhāntic Zodiac from the true sidereal zero point of the Hindu Zodiac by adopting the incompatible vernal equinox of Kali 3600 (elapsed) that was 3°39′ west of the true zero point with which the vernal equinox coincided in Kali 3339 (elapsed).

Key words: Anomalistic year, Siddhāntic astronomy, Sidereal, Tropical

INTRODUCTION

The real nature of the Hindu solar year as to whether it is tropical or sidereal remains a matter of great confusion despite decades long researches in the light of modern astronomy. The scholarly opinions are at variance with each other as can be understood from the following accounts:

a) " The position of Sun at any point on the horizon of any locality is specified by its declination, so it is evident that this method will yield tropical year and not the sidereal year. Thus it is clear that by the word "year" the Hindu astronomers of the pre-Siddhāntic period meant tropical (*sāyana*) year. In fact they were not aware of sidereal (*nirayana*) year. This very traditional way of determining solar year is found in the *Siddhāntaśiromaṇi* of Bhāskarācārya and other Siddhāntic texts but we do not find any method of determining really sidereal year in any Siddhāntic text of Indian Astronomy. In fact almost the same was the situation in other traditions of older times. It was Piccard who actually determined the sidereal year-length by taking record of right ascensions of Sun at specific times with an interval of 46 sidereal years (AD 1699-1745).

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From what has been discussed, it is evident that the Hindus in fact never intentionally used sidereal year. In all experimental methods (described in Siddhāntic texts) one gets only the tropical year and never sidereal year.[1]

b) "Ostensibly the year is sidereal. All the Siddhāntas except the Romaka give the sidereal year, and that very nearly equal to that of this school.[2]

According to the rule given by him here, the amount of precession is 59″.5 per annum. It is about 9″ more than the actual. This error is due to the fact that the Siddhantic solar sidereal year is very nearly equal to the anomalistic period and contains an error of about 8″. 5 which implies that the first point of Meṣa has a progressive motion of about 8″.5.[3]"

c) "The length of the solar year of the *Sūrya Siddhānta* has been compared with the modern value as well as that given by the Greek astronomers Ptolemy and Hipparchus. Hipparchus's value was used by *Romaka Siddhānta*. *Sūrya Siddhānta* however did not use the length of the sidereal year as given by Ptolemy, which incidentally was more accurate, but calculated their own values.[4]"

d) "The following table gives a clear picture about the difference in the two *Sūrya-Siddhānta's* in the length of a solar year. We are also giving the comparative lengths as per the latest scientific discoveries i.e. as on 1.1.1956 of both tropical and sidereal years.

Sūrya Siddānta of Varāha Mihira $365^d6^h12^m36^s$ = 365.25875 days
Current *Surya Siddhānta* $365^d6^h12^m56$ = 365.258756 days
Ptolemy (sidereal) $365^d6^h9^m48.6$ = 365.256813 days
Correct length of sidereal year $365^d6^h9^m9^s.7$ = 365.2563624 days
Correct length of tropical year $365^d5^h48^m45^s.7$ = 365.24219 days

How did the Indian savants can have such a wrong value for the length of the year?

The year according to the *Sūrya Siddhānta* is meant to be clearly tropical, but as the Indian savants compiling the *Sūrya Siddhānta* were ignorant of the phenomenon of precession of the equinoxes they were possibly unaware of the distinction between the sidereal year and the tropical year .[5]"

The question raised by the Calendar Reform Committee is still to be answered satisfactorily. The present article is a discussion on the cause of the above discrepancy in the value of the Hindu solar year.

Certain obvious factors relevant in the discussion

(a) Interpretation of the *Sūrya Siddhānta* year as a wrong tropical year is untenable because the Hindu astronomers like Āryabhaṭa were no less inferior in physical conception and mathematical techniques (as is evident from the principle of Earth's rotation, use of R-sines etc.). However, they could have used the right value of tropical sidereal year from the Greek data.

Pañcasiddhāntikā III.35[6] provide irrefutable demonstration of the fact that the Hindu astronomers were aware of the consequences of the Romaka's tropical year length and they did reject the same in view of sufficient reasons.

(b). The Siddhantic solar year of 365.25875 days is closer to the modern value of the anomalistic year of 365.25963 days and as such the simple and straight forward identification of the Siddhantic solar year is that it is 'anomalistic' in origin. Leaving such a simple inference aside a wrong identification is made, as can be found reflected in the question raised by the Calendar Reform Committee.

(c). A few researchers have restricted themselves to the drawing of superficial conjectures rather than investigating the circumstances that led to such a wrong tropical year. Conflict of the opinions (a) and (d) with (b) and (c) must be specially noted. The 'error' involved is of lesser degree if we interpret the Siddhantic value as 'sidereal' as opined by K.V. Sarma and *Pañcasiddhāntikā* III.35 is substantiative of the Hindu 'sidereal' perception i.e. *Caitra pourṇamī* falling over Hasta or Citra rather than over Puṇarvasu after a lapse of 6855 years with the use of the tropical year of Romakā. Identification as 'tropical' is a consequence of the confusion created by the coincidence of the tropical and Siddhāntic zodiacs at the epoch of Kali 3600.

Salient features of the siddhāntic Zodiac and Anomalistic year.

(a) Epochs of 'Kaliyugādi' (Ko) and 'Kali 3600 (elapsed)' (K_{3600})

Studies in the light of modern astronomy have shown that the *Ārdharātrikā* system of Āryabhaṭa and the old-Sūryasiddhānta inter-relate the actual observed planetary positions of the epoch K_{3600} and the fictitious epoch Ko (midnight of 17/18 February 3102 BC) where- in all the planets supposedly had mean synodic super-conjuction at 'Aśvinyādi' or 'Meṣādi'. The vernal equinox of K_{3600} is generally accepted as coincident with the initial point of the Siddhāntic Zodiac i.e. the mean Sun corresponding to the expiry of 3600 Kali years.

An interesting feature of the Siddhāntic zodiac can be understood by a glance over the positions of Sun and its aphelion for the above epochs (Table 1). It is apparent from Table 1 that at both the epochs Ko and K_{3600}, the anomaly is the same (nearly 77°) i.e. the Siddhāntic mean Sun and aphelion were relatively at the same positions and hence the intervening period must obviously be an integral multiple of the anomalistic year. In other words, it can be seen that the mean Sun of 'Kaliyugādi' as per modern computation with reference to the vernal equinox of K_{3600} is roughly 8° west of the Siddhāntic zero point, and to account for this deficiency the Siddhāntic year had to be in surplus by an amount of 0.00222 days i.e. 365.256450 (value of AD 500) + 0.00222 = 365.2587 (approx). But this value is slightly short of the anomalistic year (modern value is 365.25963 days) and this discrepancy can only be traced to the Siddhāntic zero

Epoch	Sun	Sun (Modern astronomy)			Aphelion (Siddhāntic)				Aphelion (Modern astronomy)			Anomaly	
	Siddhāntic	Tropic-al	Sidereal with reference to...		Ārdha-rātrika-pakṣa	Āryabh-atīyā	Pañcasi ddhāntikā	Ptolemy	Tropical	Sidereal with reference to			
			Equinox of K_{3600}	Equinox of K_{3339}						Equinox of K_{3600}	Equinox of K_{339}	Siddhā-ntic	Modern
K_0	0°/360°	301° 45′ 43″	352° 08′12″	348° 26′	80°	78°	75°		13° 43′	64° 5′	60°23′	77° average	72°
K_{3600}	0°/360°	359° 42′	359° 42′	356 ° 03′	80°	78°	75°	65°30′ AD150	77° 02′	77° 02′	73°23′	77° average	77°

Table - 1 : Solar Anomaly for Ko. and K_{3600}.

point viz., the vernal equinox of K_{3600} that was at 50° 22′ west[7] of the venal equinox of K_0. Even though the Siddhāntic aphelion is the same at K_0 and K_{3600} the relative positions of the mean Sun or Siddhāntic zero point of K_0 and K_{3600} had a shift of 3° 40′ with reference to the vernal equinox. The K_{3600} - K_0 period would have been an integral multiple of the anomalistic year only if the anomaly is the same i.e. the sidereal position of the Sun is also the same at K_0 and K_{3600}. In fact the equinox of Kali3339 (elapsed) was coincident with the point that gave the same anomaly as Ko, rather than the equinox of K_{3600} which was 3° 40′ west of the true zero point i.e. the equinox of K_{3339}. If we take the modern value of the sidereal and anomalistic years it can be seen that

3600 (365.25963 - 365.25636) = $11^d\ 46^{gh}$

i.e. 3600 (365.25875 - 365.25645) + 3° 40′ approx.

From the Table 1 also it can be understood that the sidereal mean Sun with reference to the vernal equinox of K_{3600} as per modern astronomy is 11° 40′ (approx.) west of the Siddhāntic zero point.

It is, therefore, apparent that the Hindu Solar year is the result of an application of the anomalistic year on a wrongly conceived sidereal zodiac which includes an *ayanāṁśa* of 3° 40′. The decrement relative to the true anomalistic year in fact is the contribution of the departure of the Siddhāntic zodiac from its true sidereal zero point by -3° 40′.

(b) 'Anomalistic' - 'Tropical' mix up of the 'Siddhāntic' Zodiac.

It may be noted that:

(i) The original value of 365.25875 days can be seen in the old-Sūryasiddhānti[8] and the *Ārdharātrika*[9] system of Āryabhaṭa. Āryabhaṭa used a slightly different value of 365.25868 days for shifting the *yugādi* to the sunrise in Āryabhaṭīya[10]

(ii) Brahmagupta[11] initially used a different value of 365.2584375 days to account for the venal equinox of his date that coincided with Revati, but later on abandoned it to favour the year length and the zero point of Āryabhaṭa, in his work *Khaṇḍakhādyaka*.

Use of two different values by Āryabhaṭa to define 'Ko' differently suggest that the solar year value is based on some rationale of traditional origin rather than from his own observations. Similarly, had the values been observational Brahmagupta had no reason to abandon his more accurate (sidereal on tropical) earlier value for the Āryabhaṭa's value. In fact both these astronomers have used the solar year as tropical and their conception of the zero point was not different from the successive vernal equinoxes. This is evident from the fact that both of them have defined the beginning of Meṣa rāsi and Aśvini nakṣatra as the vernal equinox and they have not spoken about the precession of the equinoxes.

In short, the early chapter of the Siddhāntic astronomy by Āryabhaṭa, Brahmagupta etc., depict a mix-up of the sidereal or anomalistic value of the solar year with the

concept of a tropical zodiac. But it must be kept in mind that the concept of a tropical zodiac is not in conformity with the stationery high apside of the sun as seen in Āryabhaṭa's works.

Intricacy of the Siddhantic solar year and the zero point can be deciphered only if we are able to understand the "mix-up" involved in the formulation of the early Siddhāntas with the epoch of K_{3600}.

Evidence for the use of an Anomalistic year in the context of a Sidereal zodiac

(a) Revolutionary speeds are 'anomalistic'

Sine the early beginning of astronomy, Man's struggle had been to obtain a calculus consistent with the observations and as such a meticulous observation of the speed of Sun would have naturally led the astronomers to formulate the anomalistic year rather than sidereal or tropical. Mathematically the longitudinal true motion of Sun in 'D' days can be expressed in simple terms as :

$$\Theta = \frac{D}{Y} (\text{mean Sun}) + K \sin \left(\frac{D}{Y} - p \right)$$

Where 'p' is the position of the aphelion, 'Y' is the solar year and 'K' is a constant. The equation of centre "$K \sin \left(\frac{D}{Y} - p \right)$" and consequently the true motion over a period will be a constant if the year length used is anomalistic. In fact any computational method that makes use of the true motion may ultimately intercept the anomalistic year (for example in the siddhāntic computation of Moon we can find the use of the anomalistic period of 3031 days-popularly known as "kālanīlaṃ" in 'Kaṭapayādi').

Method of Vaśiṣṭhā, Āryabhṭa etc.

As regards Vaśiṣṭha's method K.V. Sarma observes as follows[12]:

"The rule gives the 'True' Sun directly, without giving the 'Mean' Sun. This is possible because this Siddhānta, like the other Siddhāntas of the period like the *Āryabhaṭīya* has taken the apogee of the Sun as fixed and so for a given day in the solar year there is a given anomaly with a given equation of centre, which means a given true sun."

Vaśiṣṭhā takes the year as 365.25 days or 1461 quarter days and expresses the true motion of Sun over different *rāśis* as[13] :

Table II

Rāśi	Number of quarter days for transit	True motion per day
Meṣa	125	0° 57′ 36″
Vṛṣabha	126	0° 57′ 8,57″
Mithuna	126	0° 57′ 8.57″
Karkaṭaka	126	0° 57′ 8.57″
Siṃha	124	0° 58′ 3.87″
Kanyā	122	0° 59′ 0.98″
Thulā	119	1° 0′30.25″
Vṛścika, Dhanu	117	1° 1′32.31″
Makara	118	1° 1′1.02″
Kuṃbha	120	1° 0′0″
Mīnā	121	0° 59′30.25″

In a scheme like this, the true motion over different *rāsis* will remain constant only if the year is anomalistic. Similar methods are in use in the computation of Moon as per "Vararuci Vākyas" which belongs to the pre-Āryabhaṭa period and also in the *Vākyakaraṇa* by Sundararāja.In fact the *Vākya* method demanded the adoption of the anomalistic period in the direct computation of the true longitudes to avoid changes in the value of the *Vākaya's* from year to year.

Rāśis and Nakṣatras - Sidereal zodiac

In the above process of computation the beginning of successive year occurred progressively 9′ ahead of the fixed initial point of the zodiac and hence the *rāśis* and *nakṣatras* could retain their fixed longitudinal arc only if an appropriate correction was applied. Perhaps this correction was prevalent in ancient times and a reflection of this tradition can be seen in Bhāskarācārya's words: "*tadbhaganāh saurokta vyasta ayutatrayaṃ kalpe*" i.e. 3000 revolutions in one Kalpa or 30 in a Mahāyuga. A discussion on the variant interpretations is available at reference (16). To quote S.B. Dixshit.[16]:

"All these are but futile attempts to stretch the words to suit a desired interpretation. Bhāskarācārya's words have been given above. In the commentary on the work he himself remarks that the number of revolutions of the equinoctial point is three *ayutas* in one Kalpa has been mentioned in the S.S." It shows that Bhāskarācārya's remark definitely means that the "S.S. has mentioned three *ayutas* as the number of revolutions in one Kalpa".... etc.

The relevant passage of *Sūryasiddhānta* begins as "*triṃśat kṛtvāh yuge bhānāṃ cakram prāk parilaṃbate*" [16] and the original reference may be to the progressive movement of initial point of the *nakṣatra cakra* viz., *Aśvinyādi* rather than the equinoctial point. It must be noted here that the Siddhantic astronomers had a precise knowledge about the phenomenon of precession of the equinoxes as is evident from their annual rate of precession 1′ (nearly), which accounts for the eastward motion of the initial point also. K.V. Sarma explains the situation as follows[17]:

> "...the amount of procession is 59.5″ per annum. It is about 9″ more than the actual. This error is due to the fact that the Hindu solar sidereal year is very nearly equal to the anomalistic period and contains an error of about 8″. 5 which implies that the first point of Meṣa has a progressive motion of about 8″. 5 , not realized by the astronomers, and calculating the procession from this point they have arrived at 59″. 5."

It is apparent from the above that probably an early phase of Siddhantic astronomy existed which made use of the anomalistic year and the sidereal initial point was maintained by accounting for the 30 extra sidereal years, that accrued in a Yuga of 4320000 anomalistic years. (i.e. $30 \times \frac{360^\circ}{432,0000} = 9''$ per year) In fact the actual difference between the anomalistic and sidereal years turns out to be roughly 11″.76 (0.0032676 days as per the modern values) and in 3600 years the east ward progress should have been 11°.76 approx. i.e. the sidereal original position of Sun at Ko =360° - 11°.76 = 348°20′ approx. This can be true only if the vernal equinox of K_{3339} coincided with the Hindu zero point which was 46°40′ west of the vernal equinox of 'Ko'. The decrement of the Hindu solar year as compared to the anomalistic year arose out of the Siddhāntic zero point viz., vernal equinox of K_{3600} situated 3°39′ west of the true zero point i.e. due to the *ayanāṃśa* implicit in the Siddhāntic zodiac of the epoch K_{3600}. It must be noted here that the year length of *Braḥmasiddhānta* of Braḥmagupta formulated at the epoch of K_{3729} is less than that of the K_{3600} value (365.25875) by 0.0003125 days and in 3729 years the difference accumulates to 1.165 i.e. the zero point moves to the west by approximately 1 degree to coincide with Revati (Zeta Piscium) in K_{3729}. Similarly on the opposite side as we move from K_{3600} to K_{3339}, the Hindu solar year would have increased to reach the correct anomalistic value and the true zero point of the Hindu Vedic zodiac viz., "*Mūlādhāra Cakra*"[18].

Greek Influence Upon Indigenous Sidereal Astronomy

The history of Greek astronomy and astrology indicates that the pre-Hipparchian Greeks reckoned the longitude of all heavenly bodies along the arc of the ecliptic intercepted between the fixed point in the fixed zodiac and the great circle passing through the poles of the equator and the heavenly body. Hipparchus shifted the zero

from the fixed initial point to the moving vernal equinox and measured the longitude along the ecliptic between the vernal equinox and the great circle passing through the poles of the equator and the heavenly body. Ptolemy modified the method further by measuring the longitude along the arc of the ecliptic intercepted between the vernal equinox and the great circle passing through the poles of the ecliptic and the heavenly body.

It is quit likely that similar changes might have taken place in the realm of Siddhantic astronomy also. The early books on the Hindu astronomy do not give the definitions of Siddhantic celestial longitude. In later works the arc intercepted between vernal equinox and the great circle passing through the poles of the equator and the heavenly body was used as the stellar longitude. But the planetary longitudes were measured differently along the ecliptic as elongation from the Sun and the practice demonstrates the absence of a clear rationale as regards the sidereal initial point. Except for the Kali years at which the mean Sun coincided with the vernal equinox i.e. like K_{3600}. of Āryabhaṭa or K_{3729} of Brahmagupta. Hindu Siddhāntas since A.D. 500 never had the vernal equinox or a fixed initial point as the zero of their longitudinal measurement. Both Āryabhaṭa as well as Brahmagupta had "false sidereal" zodiacs having vernal equinox as the zero point and devoid of any precession of equinoxes. Obviously Siddhāntic astronomy of the post Āryabhaṭa period had an era of confusion during K_{3600} to K_{3729} even though it is regarded as a period of great improvement in scientific methodology.

We have only very little information about the pre -Āryabhaṭa phase and hence the history of Siddhantic astronomy cannot be reconstructed satisfactorily. Further the *apauruṣeya* doctrine that we see in *Sūrya Siddhānta* regarding the origin of astronomy makes the matters worse and point towards pre-historic roots or in other words the Siddhāntic astronomy appear today as excavated out of a dark age by Āryabhaṭa and his contemporaries. As it happens in archaeology these excavators might have tried to fill in the gaps appropriately to shape a complete system of knowledge. But unlike archaeology, here the endeavor being intellectual to derive a system of knowledge suited to their times by making use of the ancient wisdom, modifications might have been necessary. The temporal frame of this new development phase can be estimated roughly as 5th and 6th century AD.- a period in which probably the Ptolemaic or the Greek theory also made its presence felt over the indigenous perceptions. As such the 'Siddhāntic astronomy' carries in it the original conception of a sidereal zodiac, but the Greek (Ptolemaic) influence i.e. the choice of vernal equinox as the initial point, reduced it into a new situation and hence we have got a solar year incompatible with the choice of the initial point. In the works of Āryabhaṭa, Brahmagupta etc., choice of vernal equinox as the zero point obviously demanded the adoption of the tropical year, the value of which was available to them in *Romaka Siddhanta*. But the Siddhantic

tradition were unable to forego the sidereal conception and ended up in amalgamating two incompatible ideas and consequently the solar year length of the Siddhāntas appeared to be an enigma to modern researchers and this is reflected in the question raised in the Calendar Reform Committee report: As regards wrong value for the length of the year as shown elsewhere[20] the pre-siddhāntic zodiac and the Babylonian zodiac of the Seleucid era (BC 300) were 'sidereal' having a fixed initial point and this zodiacal conception can be dated back to the Vedic times. This ancient zodiac had its initial point defined in terms of fixed longitude (240 degrees) of the fiducial star "Mūla". The anomalistic year was in use and the progression towards 'east' had to be corrected annually.

Conclusion

Analytical considerations suggest that the Siddhāntic solar year is anomalistic in origin. Ancient Hindu practice of *Vākya* based computation which relied upon the true motion of the celestial bodies demanded fixed anomaly for successive days of the year, so that the same set of *Vākyas* can be used over a number of years. Obviously the *rāśis* had to be reckoned from a fixed initial point and Sun required a fixed apogee and the anomalistic period. The decrement of the Siddhāntic year length as compared to the true anomalistic value is a consequence of the modification of the original sidereal initial point with the incompatible vernal equinox of K_{3600} probably under the influence of the Greek theory of Hipparchus of Ptolemy. The vernal equinox that coincided with the true initial point of the "true" sidereal zodiac i.e. *Mūlādhāra Cakra* can be identified as that of K_{3339}.

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