VĀKYAKARAṆA – A STUDY

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The present paper is an attempt to examine the computation technique of the treatise *Vākyakaraṇa* in the light of modern astronomical algorithms. Planetary longitudes that the text provides for various epochs have been contrasted with the modern values after accounting for the precession of the equinoxes as per the *ayanāṃśa* formula prescribed in the treatise. Sun, Moon and Mars are remarkably accurate but the positions of Mercury, Jupiter and Saturn are not very precise when compared to the modern results. Longitudinal arcs gained by the planets in successive *parivṛttis* also have been contrasted with the corresponding modern astronomcal data.

Keywords: Aphelion, Synodic period, *Vākyakaraṇa*.

1. Introduction

Vākyakaraṇa[1] is the basic text of the Vākya-pañcāṅga (almanacs) prevalent in the Tamil country and it was published in 1962 by the Kuppuswamy Sastri Research Institute. This critical edition prepared by Kuppanna Sastri and K. V. Sarma contained the commentary *Laghuprakāśika* of Sundararāja along with a valuable introduction and resume of the text in English. As is evident from the discussion made by these editors, the treatise is of anonymous authorship and was produced originally around 1282 AD, presumably in Kanchi (12°50'N, 79°45'E). The treatise is also known as

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[1] *Vākyakaraṇa*, Crit. ed. by T.S.K. Sastry and K.V. Sarma, KSR Institute, Madras, 1962.

Vākyapañcādhyāyī and is based on the earlier work of Bhāskara and Haridatta of the Kerala tradition. As has been pointed out by the editors, the commentary contains three references to Vararuci,[2] the legendary progenitor of the *Vākya*-based planetary computation. The commentator Sundararāja was a contemporary of Nīlakaṇṭha, the famous author of *Tantrasaṅgraha*. Both these astronomers have referred to each other and as *Tantrasaṅgraha* depicts the date of AD 1500, Sundararāja's date can be understood as around 1500 AD.

The remarkable aspect of *Vākyakaraṇa* is the ingenuity shown in circumventing the laborious Siddhāntic (computational) process of arriving at the true longitudes of Sun, Moon and Planets by making use of the same Siddhāntic theory and elements. Kuppanna Sastri and K. V Sarma have discussed the rationale of the *Vākya*-method in their introduction to the critical edition referred to above. Basically the method relies on the fact that the equation of center vanishes at the aphelion/perihelion and for planets the geocentric longitude can be derived as the sum of true velocity of the planets relative to Sun. In terms of innovations or advancement in the then prevalent astronomical or mathematical methods, the text has little or almost nothing to offer and the main question that emerges on a perusal of the treatise is upon the accuracy of the derived true longitudes. The popularity of the work in Tamil areas and the adoption of the technique by mathematicians like Saṅgamagrāma-Mādhava point towards the efficacy of the method in realizing a significant degree of accuracy in the computation of the true longitudes of Sun, Moon and planets. True longitudes available in the treatise in the from of *dhruvas* shall offer the best commentary on the observational as well as measurement skill of the medieval astronomers of Tamil-Kerala region, if examined in the light of modern astronomy. This treatise gives the position for the mean sunrise of Ujjain, when computed for the whole number of *Kalidinas* and correction has been prescribed for reduction to true local sunrise. In the present

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[2](i) *idānm ācāryavararucir eva kujaguruśaninām grahānām...* (p. 108)

  (ii) *lāghavikenācāryeṇanena Vararucinā gaṇanākramoktam* (p. 7)

  (iii) *vākyāni punaḥ punaḥ Vararucyādipraṇītni gīr naḥ śreyāḥ ityādīni* (p. 19)

study, the local station is chosen as 10°51'N, 75°00'E (GMT+5hrs), the native place of the well-known astronomer Parameśvara that forms a part of the breeding ground of Kerala astronomy, especially of the Vararuci *vākyas*. In the following part we shall successively examine the salient features of the computation of Sun, Moon and planets as per the *Vākyakaraņa*.

Conversion of the *Vākya* longitudes to modern tropical ones requires *ayanāṃsa* which according to the *Vākyakaraņa* is obtained as follows:

(Kali year–3600) = (ΔY),

Ayanāṃsa = [(ΔY) - (ΔY)/121]/60

Vākya longitude + *ayanaṃsa* = Modern longitude.

The traditional Kerala school of astronomy takes K3623 or AD 522 as the zero *ayanāṃsa* year (instead of K3600) and derives *ayanāṃsa* as (Kali year –3623)/60. It is surprising that the *Vākyakaraņa* that followed Haridatta has differed from him in computing the *ayanāṃsa*.

2. ZERO POINT OF THE TREATISE VIS-A-VIS COMPUTATION OF SUN

As shown elsewhere by the present author,[3] the zero point in the general according to Siddhāntic astronomy is the mean Sun corresponding to the expiry of the Kali year and all the Siddhāntic mean as well as true motions of planets are derived of the synodic revolutions of planets. Āryabhaṭa has differed a bit from general practice, as is evident from the *Āryabhaṭīya* wherein he has postulated the beginning of planetary revolutions and *Yugādi* on the sunrise of Wednesday, which implies the adoption of True Sun as the zero point. As the *Vākyakaraņa* follows the Āryabhaṭa tradition, a comparison of its true Sun duly corrected for precession with the True Sun of modern astronomy can give us valuable information about the zero reference of the *Vākyakaraņa*.

First step in the computation of Sun is the computation of the *Kalidina* corresponding to the end to the true solar year. The *śodhya* or *Kalikhaṇḍa*

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[3] "On the Origin of Kaliyugadi Synodic Super Conjunction," IJHS, 32 (1997) 69-86.

prescribed for Moon suggests the origin of the treatise in AD 1282 or Kali year 4383 elapsed. (In the ensuing discussion we shall denote Kali year elapsed as K with the year as subscript: K_{4383}). *Kalidina* for the expiry of the true solar year Y = 365.25Y + [(5Y-1237)/576]. For Y = 4383, *kalidina* = 1600926.6493, which puts the *meṣa-saṅkrama* at 38gh 57.48 *vighaṭis* on Wednesday. (Thus the new-year would have been on Thursday). The tropical longitude of Sun corresponding to the *meṣaṅkrama* must be equal to the *ayanāṃśa* of 12°56'31.74". Considering 18.02.3102 BC, 0600 LMT on the meridian of 75 E00 (JD = 588465.541667) as *Yugādi*, the above *kalidina* corresponds to the Julian Day Number (JD for UT) of 2189392.19096 (Wednesday 25 March 1282 AD, 16:35 UT) at which the modern apparent geocentric longitude of Sun =12°10' 51.79". Thus the equinox computed as per *Vākyakaraṇa* will be in error by (-) 45.66 minutes of arc. Almost 17 minutes of this error arise out of the *Vākyakaraṇa-ayanāṃśa*, which has a surplus of 17 minutes as compared to the traditional Kerala values. For the remaining 30 minutes of error no source could be identified. It will be interesting to note here that the above rule for the expiry of the true solar years applies with remarkable accuracy for the epoch of the *Āryabhaṭīya* as per the Kerala school viz., K_{3623}. The relevant data is : *kalidina* for the expiry of the true solar year of K_{3623} = 1323330.052. JD (TDT) = 1911795.5933206, Saturday, 19 March 522 AD, 01:00 UT : 06:00 LMT for the meridian 75°00'E. True Sun = 359° 54'.

If we follow strictly the *Āryabhaṭīya*, *Yugādi* on Wednesday sunrise will correspond to JD (UT) = 588463.5416667 and the JD(UT) for the expiry of the true solar year K3623 can be computed as 588463.5416667 + 365.2586806*3623 = 1911795.74147: 19 March 522 AD, 05:47:43 UT and Sun + 00°05'43". For K4383, this method yields *meṣa-saṅkrama* for JD(UT) = 2189392.33866 and the modern true sun is 12°19'33.51".

By either of the methods, the equinox of the *Vākyakaraṇa* differed from the modern by minus half-a-degree and thus the longitudes will be in surplus by the same amount even if we adopt the *ayanāṃśa* of Kerala tradition 12°40' for K_{4383}. Alternatively, the modern true sun 12°11' corresponding to the expiry of the true solar year K_{4383} may be taken as the *ayanāṃśa.* In

the following analysis *ayanāṃśa* as per the treatise will be used for converting the modern longitudes to corresponding sidereal value.

Vākyas employed to derive Sun

(a) For computing *saṅkrama,* the *vākyas* "*Śrīrguṇamitrādi* are prescribed to arrive at the weekday and time of the *saṅkramas* of Vṛsabha, Mithuna etc. For the year under reference application of the method yields:

1. *Meṣa-saṅkrama* = Expiry of the true solar year = 1600926.6493, which puts the *meṣasaṅkrama* at 38*gh* 57.48 *vighaṭis* on Wednesday. This corresponds to 2131hrs LMT at the location chosen 10°51'N, 75°00'E and modern Sun =12°22'56.23"

2. *Vṛsabha-saṅkrama* : [*Kalidina* 1600926.6493] mod.7 + *Śrīrguṇamitra* (02^d-55^{gh}-32^{vigh} =2.92555 days.) This gives *saṅkrama* at 5.649294+2.92555 =8.574844th weekday of the method, i.e., on Saturday at 34*gh* 29.44*vigh.* Modern computation yield: At the station chosen the time will be 1929 hrs LMT on 25 April 1282 (JD(TDT) = 2189423.11126158) and the modern true sun is 42°12'19.41".

3. *Mithuna-saṅkrama* : Using the mnemonic 06-19-44 (or 6.3288889 days), weekday = 11.9782 = Tuesday 58*gh* 41.45*vigh* =27May 1282, 05:04 LMT, JD(TDT) =2189454.51056481 with true sun at 72° 18' 11.38".

Data is comprehensively presented in Table 1.

Annual constant used, i.e., *Kalidina* 1600926.6493 mod.7 is 5.649294. It is apparent from the above table that the *śrīguṇamitrādi vākyas* had given the *saṅkrama* with reasonable accuracy as the Sun had moved very nearly 30 degrees in each month.

True Sun

Computation of true sun during the year made use of an average true motion of 01° and another set of 36 *vākyas* known as "*Bhūpajñādi*" that accounted for the variation of speed in excess/ less than 01° and are given

Table-1

Sankrama K_{1383}	Vākya days	Weekday & Time	Date : JD(TDT) Time LMT at 10°51'N,	Modern True Sun
Meṣa		Wed. 21:31hrs		12°10'51.7"
Vṛṣabha	02-55-32 2.92555	Saturday 34gh29.44vigh	25 April 1282, 19:29 2189423.11126158	42°12'19.41"
Mithuna	06-19-44 6.32889	Tuesday 58gh 41.45vigh	27 May 1282, 05:04 2189454.51056481	72°15'11.38"
Karkaṭaka	2.93944	Saturday 35gh 19vigh	27 June 1282, 19:48 2189486.12445023	102°26'16.34"
Siṃha	06-24-34 6.409444	Wednesday 03gh 31.46vigh	29July 1282, 07:12 2189517.59944792	132°32'57.19"
Kanyā	02-26-44 2.44555	Saturday 05gh 41.46vigh	2189548.63694560	162°35'41.34"
Tulā	04-54-06 4.901666	Monday 33gh 03vigh	28 September 1282, 19:02 2189579.09249884	192°34'20.35"
Vṛścika	06-48-13 6.803611	Wednesday 27gh 10vigh	28 October 1282, 16:45 2189608.99735764	222°30'42.56"
Dhanuṣ	01-18-37 1.310277	Friday 57gh 27vigh	27 November 1282,05:08 2189638.51332753	252°26'35.73"
Makara	02-39-30 2.65833	Saturday 18gh 27vigh	26 December 1282, 13:44 2189667.87165741	282°22'27.14"
Kumbha	04-06-46 4.112777	Sunday 45gh 43vigh	25 Junuary 1283, 00:42 2189697.32859954	312°18'01.87"
Mīna	05-55-10 5.91944	Tuesday 34gh 07vigh	23 February 1283, 19:53 2189727.12790278	342°13'48.43"
Meṣa	01-15-31 1.258611	Thursday 54gh 28.46vigh	6 March 1283, 03:44 2189757.45498380	12°11'36.96"

as cumulative value for the successive 10° motion of Sun. As pointed out by the editors, the equation of center employed in *Vākya* computation is 129 sine [anomaly] as against 117 sine [anomaly] of modern astronomy. This will introduce the following errors in the equation of center :

Table-2

Anomaly	Equation of Center-*Vākya*	Equation of Center-modern	Difference
0°	0'.00	0'	0'
10°	22.40	20.32	2.084
20°	44.12	40.02	4.104
30°	64.50	58.50	6
40°	82.92	75.21	7.713
50°	98.82	89.63	9.193
60°	111.72	101.32	10.392
70°	121.22	109.94	11.276
80°	127.04	115.22	11.818
90°	129'.00	117'	12'

This difference has to be kept in mind while examining the true motion as per *Vākyas* in the light of modern astronomy. The following table gives the *Bhūpajñādi Vākyas* as well as the modern true motion in excess of 1° for the successive 10° motions of Sun:

Table-3

Sun Modern λ	Arc variation-10° in 10 days	Cumulative of Col.2	Difference Equation	Column3-Column 4	*Bhūpajnādi*
1	2	3	4	5	6
04°40'09".72	-11.64				
14°28'31".50	-14.80	-26.44	-11.69	14.75	14
24°13'43".21	-17.72	-44.16	-11.05	33.11	32
33°56'00".03	-20.87	-65.03	-10.06	54.97	54
43°35'07".75	-23.15	-88.18	-8.78	79.4	78
53°11'58".95	-25.00	-113.18	-7.22	106	105
62°46'58".71	-26.88	-140.06	-5.45	134.6	133
72°20'05".88	-27.73	-167.79	-3.51	164.28	163
81°52'22".25	-28.11	-195.90	-1.46	194.44	194
91°24'15".57	-28.38	-224.28	0	224.28	224
100°55'52".91	-27.57	-251.853	+2.08	253.93	254

Table-3 : Contd....

Sun Modern λ	Arc variation- 10" in 10 days	Cumulative of Col.2	Difference Equation	Column3- Column 4	*Bhūpajñādi*
1	2	3	4	5	6
110°28'18".54	-26.39	-278.245	+4.10	282.345	284
120°01'55".02	-25.06	-303.306	+6.00	309.31	311
129°36'51".35	-22.71	-326.019	+7.71	333.73	335
139°14'08".58	-20.19	-346.206	+9.19	355.30	358
148°53'57".38	-17.62	-363.829	+10.39	374.22	376
158°36'20".74	-14.17	-378.001	+11.28	389.28	391
168°22'10".40	-10.84	-388.838	+11.82	400.66	403
178°11'20".20	-7.67	-396.511	+12	408.5	411
188°03'39".81	-3.91	-400.424	+11.82	412.24	415
197°59'45".03	-0.01	-400.433	+11.28	411.71	416
207°59'09".86	+2.2855	-398.148	+10.39	408.54	412
218°01'26".99	5.4278	-392.720	+9.19	402	406
228°06'52".66	7.80366	-384.916	+7.71	392.63	398
238°14'40".88	9.485833	-375.430	+6.00	381.43	386
248°24'10".03	11.16733	-364.263	+4.10	368.4	374
258°35'20".07	11.83867	-352.424	+2.08	354.5	361
268°47'10".39	11.72633	-340.70	-0.00	340.7	347
278°58'53".97	11.51767	-329.180	-2.08	327.1	334
289°10'25".03	10.24566	-318.935	-4.10	315	322
299°20'39".77	8.29433	-310.640	-6.00	304.64	311
309°28'57".43	6.367166	-304.273	-7.71	296.56	303
319°35'57".46	3.534333	-300.738	-9.19	291.5	297
329°38'51".52	0.295999	-300.442	-10.39	290	295
339°39'09".28	-2.6605	-303.103	-11.28	292	296
349°36'29".65	-6.240666	-309.344	-11.82	297.52	301
359°30'15"21	-9.86	-319.204	-12	307.2	309
09°20'23".61	-12.92	-332.124	-11.82	320.3	322

Above table is illustrative of the validity and accuracy of the *Bhūpajñādi Vākyas* employed in arriving at true Sun.

3 COMPUTATION OF MOON

The process involved can be described as follows using modern mathematical notations to facilitate easy comprehension :

Kalidina -1600984 (*Śodhya*)⇒*Kalikhaṇḍa* K

K ÷ 12372⇒ Q_1 is the quotient and R_1 is the remainder.

Q_1÷ 3031 ⇒ Q_2 : R_2

Q_2 ÷ 248 ⇒ Q_3 : r, where r, the last remainder of the process is the mnemonic (*Vākya*) serial number of the *Gīrṇaśreyādi Vākyas*.

Uncorrected True Moon = *Dhruva* (=212°00'07") + Q_1*297°48'10"+

Q_2*337°31'01"+Q_3*27°44'06" +r^{th} mnemonic.

Correction in seconds of arc: $(32"*Q_3 - 8"*Q_2)*(\Delta r°-13°.18333)°$, where Δ r° is the ture daily motion of Moon obtained by subtracting the $(r-1)^{th}$ Vākya from r^{th} Vākya.

Rationale of the process

As explained above *śodhya* represents an epoch at which the equation of center is zero, i.e., Moon is at its apogee and the longitude becomes the *Dhruva* in *Vākya* computation. Longitudinal arc corresponding to anomalistic cycles such as 12372 days, 3031 days, 248 days etc. are then appropriately added to update the *Dhruva* towards the last apogee conjunction of Moon. Ultimately, the respective *Vākya* is selected and added from the 248 *Vākyas*, which represent the 248 velocities of an anomalistic cycle. Accuracy of the process can be gleaned by examining the *Dhruva* of Moon corresponding to the *śodhya* as well as at the end of the anomalistic periods 12372 days, 3031 days and 248 days in the light of modern astronomy.

Table-4

Epoch (at 10N51, 75E00)		Dhruva	Ayanāmśa* (12°56)ṅ Dhruva	Modern λ	Apogee conjunction
Kali-dina & Year	JD(TDT)				
1	2	3	4	5	6
1600984: K_{4383}	2189449.53209259 Friday, 22 May 1282, 05:35 LMT Sunrise	212°00'07"	224°56'07"	224°47'23.33"	2189449.1919171 21 May 1282. 16:36 TT
1613356 K_{4417} SR*:05:50	2201821.53109745 Monday, April 05, 1316, 05:35LMT	149°18'17"	162°14'18	140°17'11.22"	2201821.1105671 05 April 1316 14:39:13
1616387 K_{4425} SR:05:47	2204852.53056481 Monday, 23 July 1324, (TT:0044) 05:34:33 LMT	127°19'18"	140°15'18"	140°17'11.22"	2204852.7385728 23July 1324 05:43:33 TT
1616635 K_{4426}	2205100.53054630 Wed. March 27, 1325 (TT:00:44) LMT	155°03'24"	167°59'24"	168°38'53.06"	2205100.1120568 March 27, 1325 14:41:22 λ=163°41'48.68"

Correction is negligible in these cases, as we have considered one each cycle only of 12372, 3031 and 248 days.

Editors have worked out the true Moon for *Kalidina* of 1844004 as 131° 17' 32". Modern algorithms give JD [TDT] =2432469.54199235, 11 October 1947 0600 LMT: True Moon = 154° 48' and this becomes sidereally 130° 52'.

4 COMPUTATION OF RĀHU

Kalidina – 1600066 = K

[K - (9K/169809)]÷6792: Take only the remainder R_1.

R_1 ÷566 = Q_1 rāśis and remainder is R_2.

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* SR: Sunrise

$30*R_2 \div 566$ = Q_2 degrees and remainder $R_3*60/566$ = Q_3 is the minutes.

Rāhu = $360°$ − $Q_1Q_2Q_3$

As is the practice in Siddhāntic astronomy, Rāhu obtained is mean and not the true longitude. Also Rāhu has no *Dhruva* for the *Kalidina* of 1600066 days − mean Rāhu was at the zero point and hence the choice of the above *śodhya*. These aspects can be verified using modern algorithms as follows:

Kalidina 1600066 = 06:00 LMT at $10°51'N$, $75°00'$, on Thursday, November 16, 1279; JD (TDT) = 2188531.54953009: True Moon λ = $13° 55'$ $19"$ and β =$-00° 02' 44.40"$. With the *ayanāmśa* of $12° 57'$, the sidereal longitude of Moon would have been $00° 58' 19"$. Rāhu's true longitude as per modern astronomy = $14° 25' 45"$, which sidereally becomes $01° 28' 45"$. As the true Sun is $241° 03'$, the greatest inequality of the nodes is $+01°17'$ and therefore the mean Rāhu would have been at $00° 12'$ only sidereally, i.e. nearly zero (mean longitude of Rāhu by direct computation is $12° 41'$ and sidereally this is zero).

It is well evident that the location of Rāhu vis-'a-vis the latitude of Moon could be accurately fixed by the medieval astonomers. The above *śodhya* of Rāhu is a pointer towards the actual date of *Vākyakaraṇa* as the above location of Rāhu could have been fixed so accurately as zero only by observation.

Example : computation for *Kalidina* 1844004 : Para Editors of the treatise have given Rāhu = $31° 06' 34"$ (Mean). Modern algorithms give mean sidereal Rāhu as $31° 13' 45"$ − remarkable agreement for a date 700 years after the epoch.

5 COMPUTATION OF PLANETS

Similar to the use of anomalistic revolutions in the computation of Moon, planetary computations begin with a *Kalikhaṇḍa* at which the planets had been very close to their aphelia conjunct Sun, which are stationery according to the Āryabhaṭa tradition. The following table gives the positions of aphelia as per the *Āryabhaṭīya* and modern astronomy or the biggest *śodhya* given for the planet.

Table -5

Planet	Aphelion:k$_{3623}$ [Āryabhaṭīya] 21 March 522 AD, Monday 10:47:38 LMT JD [TDT]=1911797.793064	Modern astronomy	Śodhya	Modern astronomy	
				JD[TDT] 06:00 LMT	Aphelion
Mars	118°	128° 53' 20"	1552827.58333	2141293.13728009 17 July 1150	140° 23' 31"
Mercury	210°	234° 31'	1592740.36666	2181205.9168238 26 October 1259	245° 57' 10"
Jupiter	180°	170° 37' 25"	1570425.28333	2158890.83519083 21 September 1198	182° 32' 42"
Venus	90°	290° 32' 54"	1561937.73333	2150403.28635185 26 June 1175	300° 00' 20"
Saturn	236°	244° 58' 14"	1589474.46666	2177940.01710852 16 November 1250	255° 36' 41"

The table is illustrative of the basic wrong data viz., erroneous positions of aphelion employed in the *Vākya* computation of planets.

In addition of the *śohyas* and *maṇḍalas* which represent large number of synodic revolutions, each planet's motion over smaller time intervals are accounted for by considering so many synodic revolutions after which the true motions themselves repeat in view of planetary conjunction with the aphelion. These cycles of the synodic period (*parivṛttis*) for Mars are 15 of 780 days; Mercury: 22 *parivṛttis* of 116 days; Jupiter: 11*parivṛttis* of 339 days; Venus: 5*parivṛttis* of 584 days; Saturn: 29 *parivṛttis* of 378 days: Longitudinal arcs gained by the planets in the *parivṛttis* as available in *Vākyas* have been contrasted with the same computed as per modern algorithms in the succeeding part under the Tables 7 to 11.

Another data of interest is the actual date of synodic conjunctions of the planets in contrast to the *śodhyas* employed :

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* Sunrise assumed at 06.00 LMT on the meridian 75°00'E

Table-6

Planet	Apsis	Śodhya	Modern astronomy			
			Date of synodic conjunction	True [λ] longitude of Sun/Planet	Aphelion	λ– aphelion
Mars	118°	1552827.58333	1552835.313*	127°54'27"	140°23'40".1	-12°29'
Mercury	210°	1592740.36666	1592742.373	222°0'11"	245°57'10".6	-23°57'
Jupiter	180°	1570425.28333	1570426.258	185°41'20"	182°32'44".02	+03°9'
Venus	90°	1561937.73333	1561935.81	98°42'25"	300°00'15"	-201°18'
Saturn	236°	1589474.46666	1589479.888	247°1'41.65"	255°36'41"	-8°35'

(1) Dhruvas of Mars

Kalidina – 1552827.58333 = K $\Rightarrow$ *Dhruva* = -402' = -06°42'. This *Dhruva* is the elongation of the planet from its higher apses at 118°00'.

K $\div$ 132589.35 days $\Rightarrow$ Q1 and R1: *Dhruvakhaṇḍa* = Q1*27'

R_1/ 17158.61667 $\Rightarrow$ Q2 and R2: *Dhruvakhaṇḍa* = Q2* (-)504

R2/780 $\Rightarrow$ Q3 the number of cycles passed and R3 the balance of days for which the true motion has to be found out.

(a) Mars at the *Kalikhaṇḍa* of 1552827.58333: Monday, 17 July 1150 AD 19:45 LMT: JD (TDT) = 2141293.12686343. Modern True Mars = 122° 59' while true was at 120°29'37". *Ayanāṃśa* = 10°46' Sidereal Mars = 112°13'. According to the treatise, Mars is 118°–06°42' + Correction [=47'] = 111°18'+47'=112°05'.

(b) *Kalikhaṇḍa* 1552827.58333+132589.35 = 1685416.93333: 21 July 1513 Wednesday night 04:11 LMT (Sunrise at 05:47 LMT); JD (TDT) = 2273882.46833796. According to the treatise, Mars will be at [118°- 06°42'+00°27'] = 111° 45' + correction (44') = 112° 29'; in contrast the modern value is 129° 18' 15" -*ayanāṃśa* (16°46') = 112°33'.

(c) *Kalikhaṇḍa* 1552827.58333 + 132589.35+ 17158.61667 = 1702575.55.

12 July 1560, 18:57 LMT; JD (TDT) = 2291041.08264693.

Treatise gives Mars as 118° – 14°39' [Sum of *Dhruvas*, viz., -06°42'+00°27'- 08°24'= - 14°39°] = 103°21' + correction [01°43'] = 105°04'. **Modern**

astronomy gives the position 122°33' which when subtracted of *ayanāṃśa* [17°32'] gives 105°01'.

(d) *Kalikaṇḍa* of 1552827.58333 + 11699.06666 = 1564526.65 takes us to Wednesday 28 July 1182 21 : 23 LMT; JD (TDT) = 2152992.19372491.

Vākyakaraṇa gives Mars = 118° + [06°42'+10°38'=] 03° 56'+121° 36' + correction (-28') = 121°08'. Modern astronomical longitude – *ayanāṃśa* (11°17') turns out to be 121°40'.

(e) Illustration provided by the editors: *Kalidina* = 1844004. True Mars according to *Vākyakaraṇa* is 101°13'55". The modern astronomical data is:

JD [TDT] = 2432469.54198569: Saturday October 11, 1947 06:00LMT; *ayanāṃśa* as per the treatise is 23°56'. Modern True Mars = 125° 39' 23.45". Sidereal Mars will be = 101°43'23.4".

Apart from these *Dhruvas*, we may also examine the longitudinal arcs given for the successive *parivṛttis* of 780 days in the light of modern astronomy. The relevant data is provided in the table below :

Table -7

General Features of the *Vākya –Pārivṛttis* versus Modern Astronomical Data

Serial No:	JD[TDT]	Mars λ°	Mars Sidereal	*Vākyakaraṇa* λ at 780 days of *parivṛttis*	Arc difference per 399 days Modern	*Vākya*
1	2141300.856	127.908	117.148	118°		
2	2142080.856	171.570	160.8099	161.583	43.662	50.283
3	2142860.856	217.639	206.8792	207.667	46.069	46.084
4	2143640.856	268.289	257.5292	50.650	260.050	52.383
5	2144420.856	322.834	312.0741	314.817	54.545	54.767
6	2145200.856	16.756	5.995597	08.933	53.912	54.116
7	2145980.856	66.204	55.4426	57.300	49.449	48.367
8	2146760.856	111.409	100.6487	101.217	45.204	43.917
9	2147540.856	154.922	144.1622	144.85	43.513	43.633
10	2148320.856	199.741	188.9806	189.3	44.818	44.45
11	2149100.856	248.488	237.728	239.267	48.747	49.967
12	2149880.856	301.883	291.1228	293.783	53.395	54.516
13	2150660.856	356.680	345.9201	348.583	54.797	54.8
14	2151440.856	48.053	37.29317	39.517	51.373	50.934
15	2152220.856	94.660	83.90012	84.533	46.607	45.016
16	2153000.856	138.468	127.7084	128.15	43.808	43.617

A comparison of columns 3 & 4 as well 5 & 6 is illustrative of the accuracy of the technique that prevailed almost a thousand years ago, in the pre-telescope era of astronomy.

(2) Epochs of Mercury

(a) Biggest *śodhya* is 1592740 days 22 *ghaṭīs:* For convenience sunrise at the local station chosen is taken as 06:00 LMT and accordingly JD [TDT] for the date is 2181205.9168238 and modern true Mercury is 218°48'32.37". *Ayanāṃśa* as per the treatise is 12°34' and hence the sidereal Mercury is 206°15'. *Vākyakaraṇa* gives *dhruva* as (-) 32' and as the aphelion was at 210° the sidereal longitude of Mercury turns out to be 209°28' + Correction (=+2') = 209°30'. In fact the true longitude of Sun is 219°59' and as such Mercury was heliacally set at this epoch.

(b) Next *maṇḍala* given is of 16801.9 days, which takes us to *Kalidina* = 1609542.266. *Dhruva* totals to (-) 32 + (-) 1 = (-) 33 and so mercury for the treatise is 210° - 33' + 2' = 209°29'. JD [TDT] = 2198007.81682: 26 October 1305 12:26 LMT: Modern algorithms give:

Mercury = 219°19'44.53" ; Sun = 220° 44' 35.31" and Mercury's aphelion at 246°40'. As per the treatise, *ayanāṃśa* is 13°19' and as such sidereal Mercury can be computed as 206°01'.

It is apparent from the above that the period of 16801.9 days perfectly matched with complete sidereal and synodic revolution of Mercury.

In the case of Mercury neither sidereal longitudes (columns 3 & 4 in Table 8) nor the arc durations over the 116 days interval (columns 5 & 6) are in agreement.

(3) Jupiter

(a) *Śodhya* given is 1570425.283333, corresponding to JD [TDT] = 2158890.83552083: 21 September 1198 12:48 LMT. *Dhruva* is (-)261' and Jupiter 180°- 4°21' + Correction (= +22) = 175° 39'+22' = 176° 01'. *Ayanāṃśa* is 11° 33'. Modern astronomy gives Jupiter = 185°28'45" and Sun = 184° 44'. Sidereal longitude of Jupiter will be 173° 56'.

Table-8

General Features of the *Vākya –Parivṛttis* versus Modern Astronomical data

Serial No:	JD[TDT]	Mercury Modern λ°	Mercury Sidereal	*Vākyakaraṇa* λ° at 116 day of *Parivṛttis*	Arc difference per 116 days Modern	Arc difference per 116 days *Vākya*
Col.⇒	1	2	3	4	5	6
1	2181207.916	222.003	209.436	321.88		
2	2181323.916	329.351	316.784	81.033	107.348	119.153
3	2181439.916	91.084	78.517	194.283	121.733	113.25
4	2181555.916	206.537	193.970	305.167	115.453	110.884
5	2181671.916	312.959	300.392	63.833	106.422	118.666
6	2181787.916	72.835	60.268	178.417	119.876	114.584
7	2181903.916	190.872	178.305	288.5	118.037	110.083
8	2182019.916	296.910	284.343	46.367	106.038	117.867
9	2182135.916	54.547	41.980	162.083	117.637	115.716
10	2182251.916	174.916	162.349	271.967	120.369	109.884
11	2182367.916	281.156	268.589	28.767	106.241	116.8
12	2182483.916	36.388	23.821	145.767	115.232	117
13	2182599.916	158.592	146.025	255.583	122.204	109.816
14	2182715.916	265.629	253.062	11.067	107.037	115.484
15	2182831.916	18.481	5.914	129.167	112.852	118.1
16	2182947.916	141.846	129.279	239.45	123.365	110.283
17	2183063.916	250.254	237.687	353.717	108.407	114.267
18	2183179.916	0.910	348.343	112.300	110.656	118.583
19	2183295.916	124.641	112.074	223.517	123.731	111.217
20	2183411.916	234.940	222.373	336.517	110.300	113
21	2183527.916	343.726	331.159	95.60	108.786	119.083
22	2183643.916	106.993	94.426	207.85	123.267	112.25

(b) The first *maṇḍala* given (474875.45 days) is more than 1300 years. Considering the 4th maṇḍala given, i.e., 30315.28333 days, we arrive at: *Kalidina* = 1600740.5666: Jupiter as per *Vākyakaraṇa* will be 180° + [-261'-71'] + correction (+28') = 174°56'. *Ayanāṃśa* = 12°56'. By modern algorithms JD [TDT] = 2189206.11580787: Saturday, 20 September 1281. Jupi-

ter = 185° 31' 51" and Sun = 184° 54'54". Sidereal value of Jupiter will be
172° 36'.

Table-9

General Features of the *Vākya –Parivṛttis* versus Modern Astronomical data

JD [TDT]	Jupiter λ°	Jupiter Sidereal	Corrected for apsis at 180°	*Vākyakaraṇa*	Arc difference Per 399 days	
					Modern	*Vākya*
1	2	3	4	5	6	7
2158891.801	185.689	174.139				
2159290.801	216.642	205.092	210.953	210.833	30.953	30.833
2159689.801	248.412	236.862	242.723	242.083	31.770	31.250
2160088.801	281.492	269.942	275.803	274.700	33.080	32.617
2160487.801	316.028	304.478	310.340	309.167	34.537	34.467
2160886.801	351.648	340.098	345.959	344.733	35.620	35.567
2161285.801	27.479	15.929	21.790	20.500	35.831	35.767
2161684.801	62.538	50.988	56.849	56.117	35.059	35.617
2162083.801	96.197	84.647	90.508	90.133	33.659	34.017
2162482.801	128.404	116.854	122.716	122.567	32.207	32.433
2162881.801	159.556	148.006	153.867	153.700	31.152	31.133
2163280.801	190.287	178.737	184.598	184.517	30.730	30.17

(4) Venus

(a) *Śodhya* = 1561937.73333. *Dhruva* = + 17' and so Venus = 90°17' (cor-
rection is almost zero). *Ayanāṃśa* works out to be 11° 10'. Modern algo-
rithms give the date as JD[TDT] = 2150403.28634185: Thursday 26 June
1175 23:36 LMT: Venus = 101° 05' and Sun = 100° 33'. Sidereally Venus
= 89° 55'.

(b) Considering the 4th *maṇḍala* of 44962 days 23 *ghaṭīs (dhruva* = +2103'),
we may further examine the epoch of *Kalidina* = 1606900.116666: Venus
= 90° + 35° 20' = 125° 20'. *Ayanāṃśa* = 13° 12'. Modern algorithms give
the details: JD[TDT] = 2195365.66562556; Saturday, August 1298 08 08:48

LMT: Venus = 137°52' and Sun = 136°35'. Sidereal longitude of Venus will be 124° 40'.

(c) Editors have computed Venus for *Kalidina* 1844004 as 182° 26' 27". In the light of modern astronomy the true longitude of Venus at 06:00 LMT will be 206° 50'. On deducting the *ayanāṃśa* of 23°56' we get the sidereal value as 182° 54'.

Table-10

General Features of the *Vākya –Parivṛttis* versus Modern Astronomical data

Serial No:	JD[TDT]	Venus λ°	Venus Sidereal	Vākyakaraṇa λ at 584 days of Parivṛttis	Arc difference per 584 days	
					Modern	Vākya
	1	2	3	4	5	6
1	2150401.353	98.707	87.537	90		
2	2150985.353	315.400	304.230	306.283	216.693	216.283
3	2151569.353	169.470	158.300	160.400	214.070	214.117
4	2152153.355	26.638	15.468	17.667	217.168	217.267
5	2152737.353	241.366	230.196	231.750	214.728	214.083
6	2153321.353	96.920	85.750	68.133	215.554	196.383

(5) Saturn

(a) *Śodhya* 1589474.4666 days has the *dhruva* of (-) 326'. Saturn's longitude will be 230° 34'+38' (correction) = 231° 12'. *Ayanāṃśa* = 12° 25'. By modern computation JD [TDT] = 2177940.01676852: Wednesday, 16 November 1250 AD: Saturn = 246° 23' and Sun = 241° 32'. Deducting the *ayanāṃśa* the sidereal longitude of Saturn is 233° 58'.

(b) *Maṇḍala* of 21551 days of *dhruva* (+) 43' yields the epoch *Kalidina* = 1611025.4666 with Saturn at 231° 17'+ Correction (= + 33') = 231° 50'. This corresponds to JD [TDT] = 2199491.01529801, Monday, 17 November 1309 AD 17:12 LMT (Sunrise assumed as at 06:00 LMT); Saturn = 248° 17' and Sun = 243° 14'. By deducting the *ayanāṃśa* of 13° 23' we get the sidereal Saturn as 234° 54'.

(c) Considering the addition of the smallest *maṇḍala* given to the above epoch leads us to *Kalidina* of 1621990: *Vākya dhruvas* give Saturn as 236° + [(-) 326' + 43' + 401'] = 237° 58' + Correction (-14') leads to true Saturn = 237° 44'. *Ayanāṃśa* of the treatise = 13° 53'. JD [TDT] = 2210455.5478125; Thursday 25 November, 1339 06:00 LMT: Tropical modern longitude of Saturn is 254° 59' 42" which reduces to 241° 07' on deducting the *ayanāṃśa*. For this epoch tropical true Sun was 250° 36' 32.55" while the aphelion of Saturn was at 260° 01' 32.33". Sidereally the latter would have been at 246° 09', i.e. 10° east of the Siddhāntic value.

Exhaustive computation of the planets for all the specified *maṇḍalas* is not attempted, as the above examples are sufficient to ascertain the accuracy involved in the *Vākya* process.

6. DISCUSSION ON THE ABOVE DATA

The following features of *Vākya* computation is evident from the above results:

(a) Synodic revolutions with reference to the aphelion conjunct Sun were the basis of the *Vākya* computation of planets.

(b) Longitudes of aphelion used were gravely in error at the epochs of the *Vākyakaraṇa* as well as in the Āryabhaṭa tradition.

(c) The true longitudes of planets computed are not that accurate when compared to the modern results.

(d) Tables 7-11 provide a contrast between the end-point longitudes of the *Parivṛtis* of *Kujādis* and the modern longitudes on the expiry of the successive synodic period in integer, viz., Mars = 780 days, Mercury =116 days Jupiter = 399 days, Venus = 584 days and Saturn = 378 days. The agreement is really very good when considering the fact that the *Vākya* data belongs to the pre-telescopic era of astronomy.

Table-11

General Features of the *Vākya –Parivṛttis* versus Modern Astronomical data

Serial No: Col.⇒	JD[TDT] 1	Saturn Modern λ° 2	Saturn Sidereal 3	*Vākyakaraṇa* λ at 378 days of *Parivṛttis* 4	Arc difference per 378 days	
					Modern 5	*Vākya* 6
1	2177945.429	247.028	234.611	236		
2	2178323.429	258.482	246.065	247.333	11.454	11.333
3	2178701.429	269.940	257.523	258.517	11.457	11.184
4	2179079.429	281.449	269.032	269.667	11.510	11.150
5	2179457.429	293.062	280.645	280.867	11.613	11.200
6	2179835.429	304.826	292.409	292.233	11.763	11.366
7	2180213.429	316.786	304.369	303.950	11.960	11.717
8	2180591.429	328.982	316.565	316.067	12.197	12.117
9	2180969.429	341.447	329.030	328.733	12.464	12.666
10	2181347.429	354.200	341.783	341.917	12.753	13.184
11	2181725.429	7.248	354.831	355.650	13.049	13.733
12	2182103.429	20.583	8.166	9.717	13.334	14.067
13	2182481.429	34.173	21.756	24.067	13.590	14.350
14	2182859.429	47.970	35.553	38.350	13.797	14.283
15	2183237.429	61.911	49.494	52.517	13.941	14.167
16	2183615.429	75.924	63.507	66.600	14.014	14.083
17	2183993.429	89.939	77.522	80.867	14.015	14.267
18	2184371.429	103.882	91.465	95.200	13.942	14.333
19	2184749.429	117.678	105.261	109.417	13.797	14.217
20	2185127.429	131.267	118.850	123.333	13.589	13.450
21	2185505.429	144.603	132.186	136.783	13.336	13.916
22	2185883.429	157.658	145.241	149.400	13.056	12.617
23	2186261.429	170.423	158.006	162.083	12.765	12.683
24	2186639.429	182.902	170.485	174.000	12.479	11.917
25	2187017.429	195.115	182.698	185.533	12.213	11.533
26	2187395.429	207.091	194.674	196.800	11.976	11.267
27	2187773.429	218.868	206.451	207.950	11.777	11.150
28	2188151.429	230.489	218.072	219.083	11.621	11.133
29	2188529.429	241.999	229.582	230.367	11.510	11.284
30	2188907.429	253.444	241.027	241,700	11.445	11.333

(e) It is true that the extant *Vākyakaraṇa* depicts a picture of evolution from the Siddhāntic elements of the Āryabhaṭa - Haridatta tradition. But we must note the *maṇḍalas* of planets, say for example of Jupiter [4387.73333 = 11* 398.88521] and Saturn [10964.5333 = 29*378.08757]: Using the synodic periods implicit in these *maṇḍalas* the sidereal periods could have been determined as (year length^{-1} -synodic period^{-1})$^{-1}$. Siddhāntic astronomy grew exclusively out of synodic observations rather than longer sidereal observations as can be understood from the erroneous sidereal period of Saturn [10766.065 of Āryabhaṭa or 10764.748 of *Vākyakaraṇa*] derived from the synodic period of 378.08757 days. Apsidal synodic revolutions as well as the helical rising and setting of Planets could be observed as "horizon phenomena" and had helical rising and setting of planets could be observed as "horizon phenomena" and had been the original inputs for the astronomical formulations. *The original Vākya process may therefore be precedent to the Āryabhaṭa tradition as is known from the legends about Vararuci.* Further the *Vākya* computation that makes use of true motions had been prevalent in Babylon in the Seleucid period.

Kerala, the tiny tract of land lying sandwiched between the Western Ghats and the Arabian Sea, had kept alive a distinct astronomical tradition since immemorial times. Earliest of the available remanants of this tradition are the *Candravākyas* - "*gīrṇaśreyādi*" - of Varacruci belonging to the fourth century AD, which we find applied in the *Vākyarakraṇa*. Among Vararuci's 12 legendary sons, the eldest, Meḷattoḷ Agnihotri is believed to have been born on 18 February 343 AD, corresponding to the Kali-chronogram of 1257921. This is supportive of the belief that Vararuci belonged to the fourth century AD. The *Vākyakaraṇa,* which has come to be regarded as a work of Sundararāja is probably a 12th century redaction of the original work of Vararuci as is evident from the use of *gīrṇaśreyadi vākyas* for the computation of Moon. *The theory and method of Vākyakaraṇa is essentially the same for Kujādi pañcagrahas and the Moon and as such it may not be correct to deny the claim of Vararuci for being the original composer of Vākyakaraṇa.* Apart from the underlying astronomical theory 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 had its origin and evolution before the advent of the theory of the epicycles, that is, before the revolution spear-headed by Āryabhaṭa in the sixth century AD. These factors may offer a valid explanation of the references to Vararuci in the commentary of Sundrarāja as pointed out at the beginning of this paper.

Appendix 1
Śodhyas and Maṇḍalas of Planets[4]

Planet	Śodhyas/ Maṇḍalas Days-ghaṭīs	Dhruva in minutes	Number of Parivṛttis
Mars	1552827-35	-402	
	634089-09	+4	15 Parivṛttis:
	132589-21	+27	Each of 38
	28857-41	-133	Vākyas covering
	17158-37	-504	780 days.
	11699-4	+638	Total Vākyas: 570
Mercury	1592740-22	-32	
	16801-54	-1	528 Vākyas in 22
	4750-53	+149	Parivṛttis
	2549-15	-447	
Jupiter	1570425-17	-261	
	474875-27	+0	
	125648-50	-9	
	65018-17	+133	231 Vākyas in 11
	30315-17	+71	Parivṛttis
	21539-48	-619	
	4387-44	+274	

(Cont.)

[4] Vākyakaraṇa, pp. 51-55

Appendix 1 (cont.)

	15619-44	+17	
	437945-9	0	
Venus	174594-	+29	195 *Vākyas* in 5
	88756-53	-58	*Parivṛttis*
	44962-23	+2103	
	2919-38	-144	
	1589474-23	-326	
	570534-8	+5	
Saturn	182994-23	-13	551 *Vākyas* in 29
	21551-0	+13	*Parivṛttis*
	10964-32	+401	