Mean and True Positions of Planets as Described in Gaṇitagannaḍi
A Karaṇa Text on Siddhāntic Astronomy in Kannada

B. S. Shylaja and Seetharam Javagal

Volume 9, 2021

URI: https://id.erudit.org/iderudit/1085749ar
DOI: https://doi.org/10.18732/hssa62

See table of contents

Publisher(s)
University of Alberta Library

ISSN
2369-775X (digital)

Explore this journal

Cite this article

Article abstract
The unpublished seventeenth-century Kannada-language mathematical work Ganitagannaḍi is transmitted in a single palm-leaf manuscript. It was composed by Śaṅkaranārāyaṇa Jōisaru of Śṛṅgeri and is a karana text cast as a commentary on the Vārṣikatantrasaṅgraha by Vidyaśākṣī Tyāgarāja. Gaṇitagannaḍi’s unique procedures for calculations were introduced in an earlier paper in volume 8 (2020) of this journal. In the present paper the procedures for calculations of the mean and true positions of planets are described.
Mean and True Positions of Planets as Described in Gaṇitagannaḍi – A Karaṇa Text on Siddhāntic Astronomy in Kannada

B. S. Shylaja and Seetharam Javagal

Jawaharlal Nehru Planetarium, Bengaluru, and Independent


Online version available at: http://hssa-journal.org
Mean and True Positions of Planets as Described in Gaṇitagannaḍi – A Karaṇa Text on Siddhāntic Astronomy in Kannāḍa

B. S. Shylaja and Seetharam Javagal

Jawaharlal Nehru Planetarium, Bengaluru, and Independent

INTRODUCTION

This is the second paper published in this journal concerning an astronomical manual (Sanskrit karaṇa) of 1604 CE in Kannāḍa, named Gaṇitagannaḍi, that is a commentary on Vārṣikatantra of Viddanācārya, written by Śaṅkaranārāyaṇa Jōisaru. The earlier paper discussed the first chapter which was on the exact instant when the sun enters the sidereal Aries at the beginning of a given solar year (Sanskrit meṣasankrānti) and the mean longitudes of all the planets at that instant. The present paper is on the mean positions of the planets corresponding to a count of civil days from the epoch (ahargaṇa) specified by the lunar phase (tithi) and lunar month of a given year. This is part of the first chapter itself. We include the second chapter giving the true positions which are obtained after the application of the first equation (manda) correction and the second equation (śīghra) correction for the five planets which look like stars (tārāgraha), i.e., Mercury, Venus, Mars, Jupiter and Saturn.

In the first part of this paper we provide a description of the procedure highlighting the technique used in the text. This will be followed by a diplomatic transcription of the text. The palm leaf manuscript includes both Sanskrit and Kannāḍa languages and is written in the archaic script called Nandinaṇgarī. We provide a translation of the commentary from Kannāḍa. The suggestions on

An unpublished draft of the present paper was included in the book Shylaja and Javagal 2021.

The earlier paper was Shylaja and Javagal 2020. For a description and examples of the karaṇa genre, see Plofker 2009: §4.4.1.
possible corrections for scribal errors are also discussed at relevant places. As explained in the earlier paper, the Sanskrit verses are translated in to Kannada by rearranging phrases to follow the grammar of Kannada, where generally sentences commence with adjectives of the subject and end with the verb. It may be seen that words get rearranged to follow the grammar of Kannada. A small phrase may require explanation extending to several long sentences in the commentary. The rearranged phrases with intervening meanings read as complete sentences. This is the same method taught as “meaning according to word-sequence” (anvayānusārārtha) even today.

The introduction of classical texts of Sanskrit with commentaries in regional languages was already prevalent in Keraḷa by the seventeenth century, as described by Sarma (1972; 1985), who cites several examples of texts with prose or poem in Malayāḷam interlaced between Sanskrit verses. It would be interesting to study the evolution of such texts of astronomy in Kannada, with the very first example being offered by Gaṇitagannaḍi. Among the 466 manuscripts classified as astral sciences (jyotiṣam) in the Oriental Research Institute, Mysore (Malladevaru 1983), the majority are devoted to predictive astrology. Five of them have Kannada translations, interlaced with Sanskrit verses, following the “syntactic sequence” (anvayānusārā) method. As pointed out by Gurevitch (2020), translations were initiated to bring texts within the reach of local populations. Considering the importance given to the routine astronomical calculations for Sringeri, which was a seat of knowledge, a text of this kind was perhaps in great demand.

This study presents translation at two levels. The Gaṇitagannaḍi itself is based on a translation. This translation of 1604 CE was aimed at providing an elaborate commentary with references to the original phrases as and when required. As the author mentioned in the introduction, it was for the benefit of beginners and students. He stated,

Hereafter, the power of words is used to decipher the inner meaning of the work (grantha). Sometimes the interpretations are relevant. At some places they may not appear to be related. This is so because we are dealing with a mathematically oriented subject. When we are
teaching young students who are not yet competent [with the basics],
the method of expression of the meanings of the words becomes very
important. Scholars should not mistake that there is a misinterpre-
tation or that the grammatical rules for gender and number (vaccana)
and case (vibhakti) are violated.

In this paper we have tried to follow a similar rationale, so that it will be under-
standable for present-day students and scholars who may not have previously
been exposed to the texts and methods of teaching in the medieval period. The
mathematical treatment of concepts is given priority. We have provided the or-
iginal text with the translation so that any doubt on possible deviation from the
original can be inspected immediately. We believe that this will be useful for
readers who wish to understand the mathematical techniques. As we shall see
later, the crisp and short phrases require a lengthy explanation, even to a person
conversant with the tools of mathematics. Here is an example: the commentary
for verse number 2.3 states,

The śīghrahara 10 [vyomendavaḥ] should be added to kotiphala, if
śīghrakendra is mrigādi and subtracted if it is karkyādi.

It is implied that a number 10, (called śīghrahara for a specific reason) should
be added to the result obtained and called kotiphala if the angle (called “centre”
or kendra) with which we started the entire scheme of correction, is between 0
and 180; it should be subtracted if the angle is between 180 and 360 degrees.
Thus, the English rendering requires a higher number of longer sentences. The
difficulty posed by the absence of relevant diagrams in the original manuscript
transmission is addressed by their introduction in this paper, in order to facilitate
the mathematical treatment.

2 THE MEAN POSITIONS

Generally, all the texts (Siddhānta or Karaṇa) start with the calculation of
mean positions starting from the value of the ahargaṇa itself. Gaṇitagan-
nadi too starts with a modified ahargaṇa or dyugana which corresponds to the
count from the midnight before the meṣa saṅkrānti (the date of entry of the sun
in to Aries). For the date of calculation which is referred to as desired date (iṣṭa
dina) and the average lunar day decided by the phase of moon (tithi) are known.
The calculations are done to fix the tithi of the phase of the moon corresponding
to the date of entry of sun in to Aries (saṅkrānti). Since the year is reckoned on the
first day after new moon before the meṣa saṅkrānti, given as caɪtra śuddha pratipat,
the meṣa saṅkrānti need not coincide with this. It is here that the method differs
from that of other texts such as Karaṇakutūhala (Balachandra Rao and Uma 2008)
by Bhāskarācārya, where the ahargaṇa count is directly used to get the mean longitudes. In a later text, the Grahalāghava by Gaṇeśa Daivajña, the total number of civil days is regrouped in to cakras of 11 years and a modified number is used for deriving the mean longitudes of all planets (Balachandra Rao and Uma 2006).

For the Moon, from the described procedure, it is clear that the mean motion is taken to be $12 + \frac{12}{68} + 1$ degrees per day. The procedure requires that the longitude of the moon obtained in units of rāśi, degrees, minutes and seconds, be converted in to one unit namely degrees. Since rāśi is 30 degrees, its count is multiplied by 30 and added to the degrees count. For example, if the longitude of the moon is 1 rāśi and 10 degrees, it is equivalent of 40 degrees. To get the tithi we have to divide this number by the motion of the moon per day. The procedure states that division by 12 should suffice and the quotient is not needed. It should be noted that the words bhāga, aṃśa and bhāgi are used interchangeably for degrees. Thus conversion to degrees and division by 12 provides the sankrānti tithi, which is used for the exact calculation of dyugana. This provides the count of the month since the solar month starts from sankrānti tithi. Days from caitra śuddha pratipat to the date of interest are counted including the intercalary month if applicable. The number corresponding to that of sankrānti tithi is then subtracted. Here the idea of ṛtu (can be understood as season, a year has six ṛtus) is introduced to avoid one step of calculation. (Each ṛtu means 2 months). Therefore, dyugana count from the meṣa sankrānti is obtained.

Let us take an example. In the year śaka 1069 (corresponding to 1147 CE) the meṣa saṅkrānti occurred on 5th day after full moon in the month of Caitra based on a stone inscription (Shylaja and Geetha, 2016). This corresponds to March 24 as verified by another inscription recording a solar eclipse of the same year. Thus there is a difference of 20 days, which will be the carried on as the difference between dyugana and ahargaṇa (which starts from Caitra śu 1) counts.

After getting the number of dyugana, its verification is done by the week day by dividing by 7. The remainder zero corresponds to Thursday, 1 corresponds to Friday and so on. The difference between dyugana and sāvana dhruva (it is the longitude for the beginning of the year for the planet as explained in the earlier paper) is called pada and is expressed in ghāligē and vighāligē. The subtraction is explained step by step. Thus pada defines the number of days to the desired date as counted from the meṣa sankrānti, (defined as the First point of Aries in the current usage of spherical astronomy text books) effectively, the longitude expressed in units of days.

A quantity called pada was used in Vaśiṣṭasiddhānta as described by Shukla (2016, p502). It was coined as $\frac{1}{248}$th part of the motion of the moon, equivalent to $\frac{1}{9}$th of a day. Similar definitions existed for Jupiter and Saturn too, to derive the longitude. It referred to unequal divisions of the planets’ motion in a sidereal revolution. Here, in Vāṛṣiktantra, the definition itself is different. Lalla also
has defined similar divisions in Śiṣyadhīvoreddhidatantra (Chatterjee 1981). But that definition also is very different - the word used is pāda, which means a quarter. In the conventional methods (example Karanakutihala) the ahargana count is converted to the dhruvaka (longitude) and added to the dhruvāṃśa obtained earlier. Here the same procedure is adopted to get the dhruvaka using the quantity pada.

Therefore as a first step, pada is converted to units of degrees, arc minutes and arc seconds by dividing by 70. All the steps for this are explained - the first division gives degrees. The remainder is multiplied by 60 and then divided by 70 to get ghalige. The remainder of this is again multiplied by 60 and divided by 70 to get vighalige. This gives the mean longitude of the sun (stated as Ravi). The rationale for this is explained in the next sentence - the mean gati (daily motion) of Ravi 59′ (arcmin) 8″ (arcsec), which is expressed as

\[1 \text{ deg} - 52 \text{ arcsec} = 1 - 52/3600 \text{ deg}\]

Now, 52/3600 is very close to 1/70. Hence the motion of the sun is taken to be (1 − 1/70) degree per day. So, when the pada (in days, ghalige and vighalige) is divided by 70 and the ratio is subtracted from itself, the result would be the mean longitude of the sun in degrees, arc minutes and arc seconds, as the mean longitude is zero at the meṣa sankrānti.

For Mars, Mercury, Jupiter, Venus, Saturn, Moon’s nodes and the Moon’s apogee, the mean daily motions can be inferred to be: \(4/229, (4/30 + 1/325), 1/361, 40/749, 1/897, 1/566\) and \(3/808\) rāśis, respectively. The values in degrees per day are found by multiplying these by 30. The mean longitudes for any ahargana would be

\[\text{dhruvāṃśa} + (\text{pada} \times \text{gati})\]

Thus for the remaining part of the verse gati is expressed as a ratio with the values of multiplier and divisor defined in the bhūtasankhya system for all planets. In case of Mars, the conversion in to units of degree is explained. If the pada is \(a^b|c^e\), \(c\) is divided by 60 and added to \(b\), the sum is divided by 60 and added to \(a\). Thus the final value of pada is expressed in units of days. The mean motion of Mars is 4 rāśis or 120 degrees in 229 days here. Hence, numerator is 4 (in units of rāśis), expressed as kṛti, and denominator is 229 expressed as nidhi pukṣa netra here, and (pada) multiplied by the ratio is the mean motion of Mars during a pada.

For Budha śīghrocca, the multiplier is not stated explicitly. Using the idea that a plural has been used for the multiplier, the same number as for the previous one (Mars) is employed. The divisor is 30. Apart from this, to this, one has to add 1 divided by 325. Thus the correction is in 2 steps.

For the Moon, from the described procedure, it is clear that the mean motion
is taken to be equal to

\[ 12 + \frac{12}{68} + 1 = 13.17647 \]

degrees per day.

The details of the multipliers and divisors for the planets, beginning with Mars are shown in Table 1. Table 2 compares the mean motions as derived from this text with those from *Sūryasiddhānta*, depicting the accuracy of the procedure.

<table>
<thead>
<tr>
<th>Name</th>
<th>mult, div</th>
<th>Numerals in <em>Bhūtasaṅkhyā</em> system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuja/Mars</td>
<td>4, 229</td>
<td>Kṛti, nidhi pakṣa netra</td>
</tr>
<tr>
<td>Budha/Mercury</td>
<td>(4), 30 ; 1, 325</td>
<td>(kṛti), khāgni; Eka, paṅcarada - 2 steps</td>
</tr>
<tr>
<td>Guru/Jupiter</td>
<td>1, 361</td>
<td>bhū, mahi śatākṛti</td>
</tr>
<tr>
<td>Śukra/Venus</td>
<td>40, 749</td>
<td>khābdi, tāna nāga</td>
</tr>
<tr>
<td>Śani/Saturn</td>
<td>1, 897</td>
<td>kṣīti, muni randhra nāga</td>
</tr>
<tr>
<td>Rāhu/Node</td>
<td>1, 566</td>
<td>ku, rasāngaisu</td>
</tr>
<tr>
<td>Candrocca/Apogee</td>
<td>3, 808</td>
<td>thri, vasu vyoma gaja</td>
</tr>
</tbody>
</table>

Table 1: The multipliers and divisors of the planets beginning with Kuja (Mars)

<table>
<thead>
<tr>
<th>Name</th>
<th>Numerals in <em>Sūryasiddhānta</em></th>
<th>GG (this text)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candra/Moon</td>
<td>13.17635</td>
<td>13.17647</td>
</tr>
<tr>
<td>Budha/Mercury</td>
<td>4.15210</td>
<td>4.0911</td>
</tr>
<tr>
<td>Kuja/Mars</td>
<td>0.524019</td>
<td>0.524017</td>
</tr>
<tr>
<td>Guru/Jupiter</td>
<td>0.08309</td>
<td>0.08310</td>
</tr>
<tr>
<td>Śukra/Venus</td>
<td>1.602146</td>
<td>1.062136</td>
</tr>
<tr>
<td>Śani/Saturn</td>
<td>0.033439</td>
<td>0.033444</td>
</tr>
<tr>
<td>Rāhu/Node</td>
<td>0.052984</td>
<td>0.052240</td>
</tr>
<tr>
<td>Candrocca/Apogee</td>
<td>0.111383</td>
<td>0.111386</td>
</tr>
</tbody>
</table>

Table 2: The mean motions of the planets as derived in this text compared with the values from *Sūryasiddhānta*

Finally another correction for only the sun and the moon is specified. That is to add the result of *pada* divided by 150; the rationale for this is not explained here but is covered in the chapter called *Chāyādhiṅkāra*.
The mean values for all planets are for the midnight of Laṅkā (equator). Here the central meridian is described as passing through Laṅkā, Ujjain (Avanti), Roh-tak, Mānasa Sarower and another place called Svāmimale mountain (which is not mentioned in the original Vārṣiktantra). The correction for location of the observer requires the viṣuvudchāyā, which is the shadow length of a 12 aṅgula (inches) gnomon on the day of equinox. The lambajyā (R cosine) of this is multiplied by 5060 and divided by 120 to get the correction called yojanaphala.

The rationale is derived from Sūryasiddhānta (Bapu Deva Śastri 1861: vv. 1–59). The radius of earth is taken as 800 yojanas. Therefore its circumference is 5060 yojanas. Here the value for the ratio the circumference to the diameter of a circle, π, is taken as square root of 10. This calculation is needed to find the time difference between the observer’s place and the standard meridian just defined. The daily motion of each planet is different and therefore the time differences will have to be calculated individually. However, the observer is not on the equator but a certain latitude \( \phi \). Therefore the circumference will be along a circle parallel to the equator, which is obtained by multiplying the radius by \( \cos \phi \) as shown in Figure 1. Here we have the value of latitude from the gnomon shadow on equinoctial day. Therefore to get the cosine of that we have to use the sine tables (provided in the next chapter on true values) for an angle \( (90 - \phi) \). This works out to be \( 116\frac{27}{27} \). The number 5060 corresponding to the equator, is multiplied by \( 116\frac{27}{27} \) and divided by 120 so that we svadeśabhūparidhi, (the circumference of the small circle at the latitude of the observer) for the given place.

The viṣuvud chāyā is 3 aṅgula; the lambajyā is \( 116\frac{27}{27} \), can be understood as latitude, \( \phi = \tan^{-1}(3/12) = 14^\circ2^\prime11^\prime\prime \)

\[ R \cos \phi = 116\frac{27}{27} \]

From the Figure 1, the circumference of the earth at this latitude is

\[ \text{bhūparidhi} = 5060 \times R \cos \phi/120 \]

Here, 5060, \( = 2 \times 800 \times \sqrt{10} \), is taken from the Sūryasiddhānta

The \( R \) sines are to be obtained from the sine tables provided in the next chapter with the value of \( R \) as 120. This latitude of \( 14^\circ2^\prime11^\prime\prime \) refers to a location north of Śṛṅgeri (latitude \( 13^\circ25^\prime \)). However, since the author mentions the name Śṛṅgeri in the next chapter the Chāyādhikāra, this small difference may be attributed to his location in the outskirts of the town.

The next step is to get the mean values for the time of the day. This is achieved by taking the difference from midnight of the same day or the previous day. This is multiplied by the gati (or the daily motion) of the individual planets.

Thus we see that the technique offers a different approach as compared to the conventional methods (like those of the Karaṇakutūhala) in the determination of the mean positions. The multipliers for deriving the dhruvakās (longitudes) of planets have been modified suitably.
Figure 1: The circle parallel to equator at $O$ is the svadeśabhūparidhi at latitude $\phi$.

3 TRUE POSITIONS

The procedure is based on the Sūryasiddhānta but many details are not explicitly mentioned.

After getting the mean positions as explained in Section 2, the corrections to derive the true positions are performed in two steps. The first correction is called the manda correction and the second one is called śīghra. The very first verse introduces the reference points needed for the second correction, called śīghrocca. The farthest point on the epicycle created for this correction also has the same name.

From the second verse onwards the procedure for the manda correction is described.

The positions of the mandocca (apogee) for all the planets are given. Then there is an explanation for how these numbers have been arrived at. As per the definitions provided in Sūryasiddhānta (1–41 and 42), the number of years since the epoch is multiplied by the number of revolutions in a mahāyuga or kalpa and is divided by the number of years in that period to get the mandocca in revolutions. The fractional part multiplied by 360 corresponds to the position on the ecliptic in degrees for the required date. He further states there can be an error of 1 or 2 liptis (arc minutes) from the epoch specified by the Ācārya and therefore he has added 1 degree to account for such small deviations.

The word kendra is used to indicate the angle between mandocca (or śīghrocca) and the mean position (or position after manda correction). They are referred to by abbreviations manda (or śīghra). The corrections (as shown in the following discussion) derived using these are called mandaphala (or śīghraphala). It should
be noted that word *mṛgādi* is used here. All along the discussion used the zodiacal signs - here it becomes luni-solar *Mrga* corresponding to the month *Mārgaśira*.

This correction can be understood with the help of Figure 2. The basic idea of the *manda* correction is to account for the elliptical orbit, which is achieved with another smaller circle moving along the mean circular orbit. (Bapu Deva Sastri 1861).

Figure 2: Definition of *Mandakendra*

In Figure 3, at the apogee A, the planet is farthest and at B it is the closest. The planet moves along the small circle so that the distance difference is achieved over half the orbit. There is always a phase difference between the true position (shown in red colour) and the mean position of the planet (shown in black).

Since the projection of the position on the radius vector is needed for the calculation we have to get the sine of the angle called *mandakendra*, shown in Figure 1. The correction is indicated by the dashed line in Figure 3.

The next verses describe how to get the *R* sine values. In all the astronomical texts the trigonometric sine ratio is treated as the arc *R* sine (angle), called as *jyā*. In this text the word *jīva* is also used. Here *R* is taken as 120. The arc itself is expressed in units of degree (*bhūga*) arc minutes (*kalā*) and arc seconds (*vikalā*). A table is provided for the calculation of *R* sine of any angle. Every 10 degrees is termed a *khanda* (section) and the value of the differences of *R* sine is provided. The value for any intermediate value is obtained by interpolation. The numbers are specified in *bhūtasaṅkhyā*.
Figure 3: Apogee and epicycles: Black circle is the mean orbit.

The author proceeds to explain how to get the $R$ sine for any angle. The angle should be divided by 10 to identify the $khaṇḍa$. All values preceding it are added up. The $jyā$ difference corresponding to the remainder after dividing by 10 is obtained between the successive $khaṇḍa$ and added to the earlier sum. This procedure will be clear with an example. If we want find the $R$ sine for 34 degrees, we look up the value for number 3, since $34/10$ has quotient 3 ($khaṇḍa$ number) and the remainder is 4. The sum of all $jyā$ values preceding 3 is $21 + 20 + 19 = 60$. Now we have to interpolate between $khaṇḍas$ 3 and 4 for the remainder 4, as $(17/10 \times 4) = 6$ and remainder is 8. This is added to 60 as 66 and remainder 8 is multiplied by 60 to get 48'. Thus the $R$ sine of 34 is 66°48'.

The text also gives the same numbers in the reverse order as

$2|5|9|12|15|17|19|20|21|

The sums of all the preceding values of $jyā$, are provided in the next verse in the $bhūtasankhya$ system. These are termed $piṇḍikṛta jīva$.

$21|40|60|77|92|104|113|118|120$

Another interesting part introduced by the author is the table of $utkramajyā$. This trigonometric ratio $(1 - \cos)$ is not included along with the other three in the text.
books of today, although it has been named versine.

\[27|16|28|43|60|79|99|120\]

For example if the angle is 60, its utkramajyā is \( R(1 - \cos 60) \) which is 60. This is the number in the 6th khanda.

The next verse gives the values of divisors for manda corrections for the planets. Here the author follows a technique that is different from others, for example, Karanakutūhala. In most Indian texts on astronomy including Sūryasiddhānta, the computation of mandaphala is based on an epicycle model (Figure 4).

\[\text{Figure 4: Derivation of the manda correction}\]

\( P_\circ \) is the mean position of the planet. \( P \) is the position corrected for manda, referred to as mandasphuṭa. The angle MOP_\circ is called \( M \), mandakendra; the angle POP_\circ, \( \Delta \theta \), is called mandaphala. Writing \( r \) as the radius of epicycle and \( R \) as the radius of deferent, we get from triangle OQP and PQP_\circ,

\[ \Delta \theta = \frac{r \sin M}{R} \quad \text{(in radians)} \quad = \frac{r \sin M}{R} \times \frac{3438}{60} \quad \text{(in degrees)}, \quad (1) \]

where \( r \) and \( R \) are the radii of the epicycle and the deferent, respectively.
From the descriptive procedure we understand that the *mandaphala* is given as

\[
\frac{R \sin M \times 60}{x} + \frac{R \sin M \times 60}{y}
\]

where \(M\) is the *mandakendra*, and the denominator is called the corrected *mandaccheda*. Here \(x\) and \(y\) are specified for each planet. For instance, for the Sun, \(x = 32^3\) (vyomāgnidanta) and \(y = 90\) (khāṅka). The first term in the denominator is much larger than the second term.

Therefore,

\[
\frac{R \sin M \times 60}{x} + \frac{R \sin M \times 60}{y}
\]

is approximated as

\[
\frac{R \sin M \times 60}{x} + \frac{R \sin M \times 60}{y} = \frac{R \sin M \times 60}{x} \left[1 - \frac{R \sin M \times 60}{xy}\right]
\]

In the *Sūryasiddhānta*, \(r\) is of the form

\[
x' - y' \sin Mx' \left[1 - \frac{y'}{x'} \sin M\right]
\]

and \(R = 360\). For instance, for the Sun, \(x' = 14\) and \(y' = \frac{4}{3}\). In Table 3 the values for *mandaphala* from the two texts are compared.

Table 3 shows that the Ganitagannaḍi expression for the *mandaphala* would give very nearly the same results as the ones following from *Sūryasiddhānti* rules. For all planets the divisors are derived and provided using the siddhanatic values of the peripheries. The values from *Karaṇakutūhala* (Balachandra Rao and Uma 2008) are compared in Table 4.

The correction is explained in the next verse. It is called *tātkālika*, which can be interpreted as “as applicable for that instant.” The procedure to apply this correction appears to be have been devised by the author himself. The \(R\) sine of the *mandakendra* is converted to *lipti* (arcminutes) by multiplying the value in degrees by 60. Then the *liptis* are added so that the entire value is in *liptis*. These are to be divided by different numbers for each planet specified by the verse beginning with khāṅkaiḥ, 90 for the Sun and so on. The result is again added to the numbers specified earlier in the verse beginning with vyomāgnidantaḥ, to get the divisors. Dividing the \(R\) sine of *mandakendra* by this corrected divisor gives the *mandaphala*. The numbers are 90 (khāṅka), 490 (khatāna), 300, (viyadabhrarāma), 70 (khāsva) 170 (kha śailendu), 21 (indupakṣa), 380 (khaṣṭāgni). Thus the correction extends to the fraction of a degree.
<table>
<thead>
<tr>
<th>Planet</th>
<th>X</th>
<th>y</th>
<th>x’</th>
<th>y’</th>
<th>mandaphala in Ganitagannadi in degrees</th>
<th>mandaphala in Sūryasiddhānta in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ravi / Sun</td>
<td>3230</td>
<td>90</td>
<td>14</td>
<td>1/3</td>
<td>2.2291[1 − .02477 sin M] sin M</td>
<td>2.2283[1 − .02380 sin M] sin M</td>
</tr>
<tr>
<td>Candra / Moon</td>
<td>1413</td>
<td>49</td>
<td>32</td>
<td>1/3</td>
<td>5.0955[1 − .0104 sin M] sin M</td>
<td>5.0933[1 − .0104 sin M] sin M</td>
</tr>
<tr>
<td>Kuja / Mars</td>
<td>603</td>
<td>30</td>
<td>75</td>
<td>3</td>
<td>11.9402[1 − .03998 sin M] sin M</td>
<td>11.9375[1 − .0400 sin M] sin M</td>
</tr>
</tbody>
</table>

Table 3: Comparison of mandaphalas in the Ganitagannadi and the Sūryasiddhānta. Kindly provided by the anonymous referee.
Table 4: The ratios of circumferences of epicycles of planets used in this text, compared to those in the Karaṇakutūhala (KK)

<table>
<thead>
<tr>
<th>Name of planet</th>
<th>Mandacheda Divisor</th>
<th>Phrase bhūtasaṅkhyā</th>
<th>circumference of epicycle</th>
<th>circumference of epicycle (KK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ravi / Sun</td>
<td>3230</td>
<td>vyomāgnidanta</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Candra / Moon</td>
<td>1413</td>
<td>śikhirupāśakra</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Kuja / Mars</td>
<td>603</td>
<td>purānbarānga</td>
<td>70</td>
<td>38</td>
</tr>
<tr>
<td>Budha / Mercury</td>
<td>1510</td>
<td>digarthya candra</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>Guru / Jupiter</td>
<td>1371</td>
<td>rūpāgaviśva</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>Śukra / Venus</td>
<td>3769</td>
<td>amkarasādrirāma</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>Śani / Saturn</td>
<td>923</td>
<td>tripakṣarandrha</td>
<td>46</td>
<td>48</td>
</tr>
</tbody>
</table>

The final value after the correction is called mandasphuṭa (corrected for manda).

The next verse provides similar divisors śīghracheda for the second correction. Although the author declares it is on the same lines as done for manda correction, the procedure is not very clear as can be seen later. Prior to the discussion on śīghra correction, he summarises the procedure for manda in a single sentence, whose translation was also difficult. Here is the summary:

- Get the mandakendra, difference between mandocca, the apogee and the mean
- Get the $R$ sine of mandakendra and koṭi ($R$ cosine) also. (Koṭi is not needed for manda correction)
- Convert the $R$ sine in to arc minute by multiply by 60 and adding to the lipti component.
- Divide it by the appropriate number as given by the sequence stated in the verse starting with 90.
- Add the result to corresponding numbers provided by the sequence starting with 3230.
- Divide the product of 6 and $R$ sine of mandakendra by the corrected divisor.

This last step, namely dividing it by 6, was not specified in the procedure earlier. This division is necessary because while, converting it into lipti we had multiplied it by 60. Essentially, the procedure can be written in the modern notations as an equation,

$$ a = \frac{6R \sin M}{\text{corrected divisor}} \quad (2) $$
where,

\[
\text{corrected divisor} = \text{number } 3230 + \frac{R \sin M \text{(in liptis)}}{\text{Correction factor 90}} \quad \text{for the sun.}
\]

Similar devisors are derived for other planets.

The śīghra correction takes the manda corrected position as the reference. Let us first see how the correction is achieved.

The procedure for śīghraphala, which has been very aptly clarified and compared with the procedure in Sūryasiddhaṇta by the referee is being reproduced here.²

The śīghrocca for the planets is the sun itself. In the Figure 2.4, the sun, the planet and the earth are represented by S, E and P. The relevant angles are marked as \(\theta_{ms} \) mandasphuṭa, \(\theta_{s} \) śīghra, \(r \) radius of śīghra epicycle and \(R \) the radius of deferent.

\[\text{Figure 5: Derivation for śīghraphala from Sūryasiddhaṇta}\]

\[\text{śīghrakendra} = \theta_{ms} - \theta_{s} = -M_{sk} \]

\[\text{śīghraphala} = \Delta \theta, \text{ is given by} \]

\[R \sin \Delta \theta = \frac{r \sin(\theta_{ms} - \theta_{s})}{\left[\left[R + r \cos(\theta_{ms} - \theta_{s})\right]^2 + r \sin(\theta_{ms} - \theta_{s})^2\right]^{1/2}} \]

\[\sin \Delta \theta = \frac{r/R \sin(M_{sk})}{\left[\left(1 + r/R \cos(M_{sk})\right)^2 + r/R \sin(M_{sk})^2\right]^{1/2}} \quad (3)\]

² The anonymous referee of has kindly provided a critical analysis and compar-ison of this formula with the one in Sūryasiddhaṇta.
Now, let us see the procedure in Gaṇitagannāḍi.

The epicycle of the śīghra is rather large although Figure 5 represents it as a small circle of radius $d$. $S'$ is the direction of śīghroccha, the conjunction of the planet with the sun. The manda corrected position is $P_o$. By the time the mean position has changed to $P_o$ from conjunction the projection on the epicycle would have moved from $J'$ to $J$. The corresponding shift on the orbit takes it to the point $P$ as the true position.

Figure 6: Diagram for explanation of śīghraphala

From the Figure 6, we can derive an expression for the angle $\theta$, the śīghraphala. The śīghraphala, $s$ is expressed as (Somayaji, 1971)

$$R \sin \theta = \frac{d}{k}R \sin m$$

where $k$ is called the calabāṇa, $EJ$, the distance of the planet from earth at the desired instant. (Bapu Deva Sastri 1861). The word caladbāṇa also is used.

From the properties of similar triangles we can show that

$$k_2 = \left[ \frac{d}{a}R \sin m \right]^2 + \left[ d + \frac{d}{a}R \cos m \right]^2$$

(4)

The procedure requires that $\left[ \frac{d}{a}R \sin m \right]$ and $\left[ \frac{d}{a}R \sin m \right]$ be determined, these are termed bhujaphala and kotiphalas respectively. The author has used a different technique to compute $k$, the calabāṇa. The term $d$ in the expression $\left[ d + \frac{d}{a}R \cos m \right]$
has been fixed to 10. Accordingly kotiphala is added to 10 and its square is added to the square of bhujaphala, essentially getting the value of $k_2$. Its square root is the divisor for bhujaphala again to get śīghraphala.

Then the value of $a$ is adjusted as per the ratio $d/a$. For, example for Mars, the ratio is known to be 1.5 (given as the ratio of radii of peripheries with 360). If $d$ is 10 the value of $a$ will $d/1.5$. However the ratio $d/a$ will not change. It is to be noted that the coefficients of $R \sin m$ and $R \cos m$ are same. By this adjustment the coefficient of numerator in (3) also will be the same. To take care of the trijyā, multiplication by 120 also is necessary. Let us call the ratio of $d/a$ as $y$. Since $d$ is fixed at 10 the value of $a$ is $10/y$. The śīghracheda is 720 $y$ which we can write as $A$.

$$bhujaphala = \frac{y R \sin m 60}{\text{śīghracheda}} = \frac{120 \sin m 60}{A} \frac{10}{10} y = y \sin m \quad (5)$$

Similarly the coefficient of $R \cos m$ also is adjusted by dividing by $A$. This looks very tricky but we can see that it is devised to get rid of several steps such as division by 60 and 120. Thus the same Bhujaphala and Kotiphala (with $R = 120$) are

$$Bhujaphala = BP = \frac{R \sin (M_{sk})}{\text{śīghracheda}} \times 60$$

$$Kotiphala = KP = \frac{R \cos (M_{sk})}{\text{śīghracheda}} \times 60$$

Here, the divisor, śīghracheda is provided for all planets (eg., for Mars it is 1110)

The hypotenuse calabāṇa is defined as

$$\text{calabāṇa} = [(10 + KP)^2 + BP^2]^2$$

$$\text{śīghraphala} = \Delta \theta, \quad \text{is given by}$$

$$R \sin \Delta \theta = 120 \times BP \times R / \text{calabāṇa}$$

this is same as equation (3) above and is further reduced to

$$\sin \Delta \theta = \frac{720 \sin (M_{sk})}{\text{śīghracheda} \left[ 10 + \left( \frac{120 \cos (M_{sk})}{\text{śīghracheda}} \times 60 \right) \right]^2 + \left( \frac{120 \sin (M_{sk})}{\text{śīghracheda}} \times 60 \right)^2}^{1/2} \quad (6)$$

Thus if we identify $r/R$ of (3) with $720/\text{śīghracheda}$ of (4); they are identical. Table 6 lists the numbers and the implied ratios, which is in agreement with the values currently in use. Thus Ganitagananadi (GG) has the same procedure from the Sūryasiddhānta (SS) to aid calculations. (śīghrakendra as $M_{sk}$, can have any value from 0 to 90). The agreement to second decimal place implies 6′. The values of the ratios of the radii of the planets are concealed in these numbers (A) provided as śīghracheda.
This procedure has a great advantage in computations, since only bhujaphala and kotiphala are to be read out from the sine tables and the constants take care of the conversions. It can be summarized as follows:

1. Calculate the calabāṇa and ēśhrafendra for the individual planet
2. Get the bhujaphala and kotiphala putting the corresponding ēśhrafeda
3. Calculate ēśhraphala putting using (6)

Thus if we identify \( r/R \) of (4) with \( 720/ēśhrafeda \) of (3); they are identical. The comparison of the ratios are in the Table 6 below.

<table>
<thead>
<tr>
<th>Name of planet</th>
<th>ēśhrafeda</th>
<th>Phrase</th>
<th>implied ratio of orbit radii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kuja/ Mars</td>
<td>1110</td>
<td>Digīśava</td>
<td>1.54</td>
</tr>
<tr>
<td>Budha/ Mercury</td>
<td>1956</td>
<td>tarka śarāṅka candra</td>
<td>0.37</td>
</tr>
<tr>
<td>Guru/ Jupiter</td>
<td>3651</td>
<td>ku arthānga rāma</td>
<td>5.07</td>
</tr>
<tr>
<td>Śukra/ Venus</td>
<td>993</td>
<td>jvalanāṅka nanda</td>
<td>0.72</td>
</tr>
<tr>
<td>Śani /Saturn</td>
<td>6562</td>
<td>dvāṅgaṅsu tarka</td>
<td>9.11</td>
</tr>
</tbody>
</table>

Table 5: The values of ēśhrafeda for five planets and implied ratio of radii

The next step is to get the sine inverse form the same sine tables which is quite straightforward and explained already.

The next verse describes the procedure for getting the sphaṭagati, the true motion of the planet. We will see that the concept of calabāṇa has been utilized here also to lessen the steps of calculations. It is assumed that the reader is aware of the procedure and the steps are mentioned very briefly. The average value of the gati obtained as an average for one revolution is called the mean. The first step of mandasphuṭa correction uses the value of kotiphala arrived above. This procedure is not discussed here.
The correction in the second step requires the śīghra corrected value and the calabāṇa, earth planet distance, to get the sphuṭagati or the true motion. In case of the sun and the moon the second step is not needed. Here only the second step is explained. The planet earth distance which was termed calabāṇa is being used again here.

The difference between the gati of the śīghrocca (U) and that of the planet (V) is multiplied by a quantity which we shall call q, defined as the difference of the śīghrahara as per catuhpratinyāya. This phrase is not explained and the meaning is not very clear. But we try to understand the procedure and interpret. After multiplication it is divided by the same śīghrahara used for getting calabāṇa. This is added to or subtracted from the gati obtained after manda sphuṭa correction.

The sphuṭagati consists of three components - the mean motion of the planet, the mean motion after the manda correction and the mean motion after the śīghra correction. The last quantity is given by

\[ dm = U - (U - V) \times \frac{q}{\text{calabāṇa}} \]  

where \( \theta \) is the śīghraphala and \( k \) caladbāṇa, is the earth-planet distance. Here \( U \) represents the mean motion of śīghrocca and \( V \) is the mean motion of the planet. In the case of planets śīghrocca is the sun itself. Therefore \( U - V \) is a measure of the difference in speeds of sun and planet. The difference between the two becomes substantial as the planet - earth distance and the sun - planet distances have a larger range as compared to the sun or the moon. The statement above can be expressed as an equation as given in the text as

\[ dm = U - \left( U - V \right) \times \frac{q}{\text{calabāṇa}} \]  

Thus we can interpret that the quantity \( q \) is \( R \cos \theta \). The meaning of catuhpratinyāya perhaps is discussed elsewhere and assumed to be known to the reader. It implies \( 10 - (\text{śīghrahara added value}) = 10 - (10 + R \cos \theta) \), which is \( \cos \theta \), itself. The phrase used is “caladbāṇa harāntareṇa.” The word bāṇa refers to the term \( (R + R \cos \theta) \). Then, śīghrahara is 10, so the difference will be \( R \cos \theta \).

The calabāṇa is converted to arc seconds and subtracted from mandasphuṭagati if calabāṇa is smaller; that gives the sphuṭagati.

The equation \( (8) \) also shows the effect of the difference of speeds as seen from the earth. The projection of difference of speeds in the line of sight is achieved by the multiplication by \( R \cos \theta \). If \( dm \) is negative the difference implies the vakragati - the apparent reversal in the direction of motion. This idea is used to fix the onset of retrograde motion for these five planets.

The next verse mentions a correction to be done for the sun and the moon. This is described in the Sūryasiddhānta as per the verse quoted in the text. (This
verse is included in the appendix) This is called the bhujāntara correction and is needed because of the non-uniform motion of the sun. As can be guessed this is a direct consequence of the elliptical orbit.

All these computations are for midnight at Ujjain. The time difference will be determined with reference to a uniform motion of 360 degrees a day or 21600 arcminutes per day. The word cakralipti, number of liptis (arcminutes) in a cakra (circle), is used for 21600. This is the only place where kaṭapayādi system has been used to denote this as anantapura.

The procedure here is as follows:- the Rsine of the sun is converted to lipti and divided by 27; the result in liptis is added to the sun and the moon. Addition or subtraction is decided by bhujaphala (as positive or negative). That gives Ravibhujasamīskṛtacandra - which means moon corrected for Ravibhujaja. This correction is to be done for all planets. But for all the others it is quite small and therefore the author states that he specifically applies it for the moon. This correction should be done for all planets. This is as per the verse in Sūryasiddhānta (II - 46) - the gati of planets should be multiplied by Ravibhujaphala in kala and divided by 21600; the result is positive or negative as is the case for the Sun. The mean gati of the Moon is 791. Dividing 21600 by 791 gives 27. Therefore the author gives the rule as divide by 27.

This completes the second chapter called Grahasphuṭādhikāra. The colophon is identical to the one for the first chapter, with identical adjectives.

This chapter for calculation of true positions of planets has used procedures which render computations easy and simplified. The rationale for the procedures has been explained. The ratios of planetary distances and the epicycle radii are compared with those given in Karaṇakutūhala. The constants used here have been modified by the author himself and small corrections also have been incorporated.

Finally a note on the colophon: the author has attributes “like a full moon for the ocean of nectar, and, who, to the ignorant astronomers is like Garuḍa (Brahminy kite, the mythological enemy for snakes) to snakes.” The corresponding translation can have two interpretations in the absence of the specific case endings:

- Dēmaṇajyotisāgraganyasaudhārnavapūrṇacandra – can be a single phrase meaning “like the full moon for the nectar ocean of Dēmaṇa who is an expert astronomer.”
- Vāsaṅguru Dēmaṇa – can be one phrase comparing Dēmaṇa to the guru of the Gods. Now agraganya gets attributed to the ocean so that the implied meaning is “like the full moon for the nectar ocean of expert astronomers.”

Generally the ocean and full moon metaphor is used to signify happiness - akin to the high tides associated with full moon. Here the ambiguity arises with the
word *dēmanajyotisagragaṇya* leading to the above two possibilities. This is by treating the expression as a descriptive compound (*karmaṃdhāraya*) as suggested by the referee and K. R. Ganesha (personal communication).

There is yet another interpretation as provided by Mahesh and Seetharama Javagal (2020) in the context of edition of *Karaṇābharanaṇa* by the same author, Śaṅkaranārayana Joyisa. The translation of the same phrase reads

> Composed by Śaṅkaranārayana Joyisa who is “a falcon to the serpents of unaccomplished astronomers,” and
> 
> the full moon emerged from the nectar-ocean of the foremost astronomer Dēmaṇa Joyisa, the one who is equivalent to the guru of Indra.

This is based on the mythological story that the moon was churned out of the ocean (*amṛta manthana*). The simile classified as *rupakālankāra* describes the happiness of the father provided by the genius of the son. Here the fact that Dēmaṇa is the father has been utilized although not specified and *Garuda* is translated as falcon.

These titles are not found in the earlier works of Śaṅkaranārayana Joyisa, namely *Tantradarpaṇa* (1601 CE) and *Karaṇābharanaṇam* (1603 CE) where it reads

> ...composed by Śaṅkaranārayana Joyisa, the son of Dēmaṇa Joyisa, the astronomer, who is equivalent to the guru of Indra, a resident of Śṛṅgapurī. (Mahesh and Seetharama Javagal 2020)

Perhaps he was bestowed with the titles in 1604 CE. Or, did he crown himself, or, did he become more poetic?

4  **GRAHAMADHYĀDHIKĀRA TRANSLATION**

This chapter, a continuation of the verses explained in our earlier paper (Shylaja and Javagal 2020), explains getting the mean positions of all planets. Since there is an ending note stating that *Dhruvādhiṇaṇa* is concluded and *Grahamadhyādhikāra* is commencing, we may consider this as a sub-section of the first chapter. For degrees the words *bhāga* and *bhāgi* are used interchangeably. We have retained the usage in English as well.

The text is provided in the next section as is given in the manuscript which has the text in both the languages, Sanskrit and Kannada. As mentioned earlier the script is *Nandināgarī* and here we have put both languages in Kannada script. Translation and the verses from 1 to 10 of *Dhruvādhiṇaṇa* have been already provided in the earlier paper. It is to be noted that the translation is provided only for the *ṭīke* or commentary in Kannada not for the *mūla*, the original Sanskrit verses. Very long phrases have been split to shorter sentences.
Now the procedure to derive the mean values for the required date will be explained from the number of dyuṅgas, whose derivation, based on the parameters like saṅkrānti and tīthi is explained.

VERSE || 11 ||

[This is to get the tīthi of saṅkrānti.] The dhruvāṃśa, obtained earlier [for the beginning of the year], of the moon is considered. The rāśi part is multiplied by 30 and added to the degrees part so that we have it expressed in degrees. This is divided by 12 to get the quotient as the saṅkrānti tīthi. The remainder is of no consequence here.

Sāṅkrānti tīthi is defined as the number of civil days intervening from caitra śuddha pratipat to meṣa saṅkrānti for the sun [to cover it] with its mean daily motion.

[Now the calculation of dyuṅga] Number of days from caitra śuddha pratipat is counted – this should include the intercalary month if needed. The number of saṅkrānti tīthis is subtracted. Every ṛtu, season, has two months. The number of ṛtus elapsed are subtracted to get the dyurāśi. The dyuṅga is obtained by removal of saṅkrānti tīthis and ṛtus; this is the number of tīthis from the beginning of the solar year [meṣa saṅkrānti].

VERSE || 12 ||

As per [the verse starting with] “nagāpta šiṣṭa”, the dyuṅga thus obtained is divided by 7. The remainder is added to the vāra of sāvanadhruva. 7 is subtracted from it if it is more than 7.

As per [the verse starting with] “vārapatirniśīthe”, the remainder obtained is the week day number starting from Friday. If the number is 1 it is midnight of Friday; 2 implies midnight of Saturday [and so on].

FIRST LINE OF VERSE || 13 ||

This method gives the week day correction of one day more, or one day less which can be applied to the dyuṅga-count (so that the calculated and the actual week-day are the same). The sāvana dhruva should be subtracted from the corrected dyuṅga in units of ghalige and vighalige. This is how you can do it. Take out one dyuṅga [which is equal to 60 ghalige] and [write it] as 59 ghalige. Place the dyuṅga and take one from it and bring (it as) 60 (ghalige). From this, with (1 ghalige further written as) 59 (ghalige and 60 vighalige), the sāvanadhruva with ghalige and vighalige is subtracted. The result is called a pada expressed in units of day, ghalige and vighalige. (“pada” is the time-interval between the meṣa saṅkrānti

HISTORY OF SCIENCE IN SOUTH ASIA 9 (2021) 232–272
(beginning of the solar year) and the beginning of the desired day) [This is the
number] to be used for all the planets.

Now consider the pada twice – as per [the verse starting with] “khāgamśa hīn-
ena phalam”, divide the second one by 70 to get degrees. The remainder is mul-
tiplied by 60 and divided by 70 to get lipti and similarly vilipti. These values are
subtracted from the (first) pada to get the mean sun in bhāga units. That should
be divided by 30 to get rāsi. The remainder is bhāga, thus you get the mean sun
for the midnight of the desired day in units of bhāga, lipti and vilipti.

The rule applied is – for one day the mean gati is 59 lipti 8 vilipti. The math-
ematical explanation of this is that the value gets lesser by 1 bhāgi in 70 days.

SECOND LINE OF VERSE || 13 ||

[The same pada is used now for the moon.] It is multiplied by 12 specified as
arkanighnam (arka 12, nighnam, multiplication) in the verse. Two copies of the
product are kept; the lower copy is divided by 68 to get the product in units
of bhāga, and added to the upper copy. This is added to one pada. Divide it
by 30; if the result is more than 12 divide it by 12; discarding the quotient, the
remainder is the rāsi, and the lower units are bhāga, lipti and vilipti. As per the
verse “dhruveṣu yojya”, this quantity in rāsi and other units, is added to the dhrusa
for the beginning of the year (obtained earlier) for the moon to get the mean
moon for midnight of the desired day.

VERSES || 14 || AND || 15 ||

To get the mean Kuja (Mars): All the three copies of the pada are multiplied by
4 as per (the verse) “krtaghnāt.” The lower two are divided by 60 and (and the
square of 60 respectively) and added back. The sum is divided by nidhi, pakṣa,
netra that is 229, to get bhāgi. The reminder is multiplied by 60 and again divided
by 229 to get lipti and same way to get vilipti. The rāsi and sub units, obtained
this way is added to the dhrusa of Kuja (obtained earlier) to get mean Kuja.

Here kṛti [corresponds to] 4 rāṣi and nidhi, pakṣa, netra [corresponds to] 229
days, arrived at as completion of 4 rāṣi s by the mean Kuja. Therefore the rule
of three used is [as follows] 229 days correspond to 4 rāṣi – therefore how many
rāṣi for the desired number of days? It is the same procedure for all the planets
[hereafter].

Now the (determination of) śīghroccha, higher apsis of the epicycle, of Budha
(Mercury).

The divisor has been specified as 30, from “jñah khāgnibhiḥ”, in plural, but
not the multiplier. Based on the context we consider the multiplier gunaka is the
same as that for Mars namely 4. The pada is multiplied by 4 as before and divided
by 30 and expressed as rāṣi which is kept aside. Multiplying the pada by one [you
get back] the same pada. This is divided by 325 (pañcaradaiḥ) to get the rāśi units and added to the earlier obtained rāśi. This is finally added to varṣa dhruva to get Budha śīghroccha.

Now the procedure for mean Guru (Jupiter) – the multiplier is 1, specified by bhu. This is to be divided by 361 to get Guru. This [converted to units of rāśi] is added to dhruva for the year to get mean Guru.

Now the śigrocca of Śukra (Venus) – pada is multiplied by 40 and divided by 749. The result [converted to rāśi units] is added to the dhruva obtained earlier.

To get the mean Śani (Saturn) – pada is multiplied by 1, and divided by 897; the product [converted to units of rāśi] is added to the dhruva to get mean Śani.

The multiplier for, Rāhu (Moon’s ascending node) is 1. It is divided by 566. This is subtracted from the Dhruva as per tamasah pratipa, to get mean Rāhu. Adding 6 rāśis will fetch Ketu.

For getting the candrocca, (Moon’s apogee) pada is multiplied by 3 and divided by 808; the result [converted to rāśis] is added to previously obtained dhruva.

VERSE || 16 ||

Dyugana is divided by 150; the result expressed in lipti, vilipti is subtracted from the mean values for the sun and the moon. Thus all the mean positons of all planets are obtained for the midnight of Laṅka. Lanka is to be understood as the south of mahāmeru.

VERSE || 17 ||

Getting the lambajyā of the place of observation (svadeśa) is explained later in the chapter chāyādhyāya; this is multiplied by 5060 and divided by the trijyā 120, which is defined in sphuṭādhyāya. This is the svadesahāparidhi, the circumference of the small circle at the observer’s latitude. For a place with an equinoctial shadow of 3 aṅgula, the lambajyā is 116/27. The derivation of 5060 is explained as per Sūryasiddhānta in this verse.

Quotation from Sūryasiddhānta

Multiply the square of the earth’s diameter (1600) by 10 and its square root is the circumference in yojanas.

The bhūmadhyarekhā stretches from Laṅka to Meru Mountain. Rouhitaka country, Svamimale, Avanti is Ujjaini, Amarādri sāra is Mānasa Sarovara. The north south axis, sutra, passes through these and is called bhūmadhyarekhā.
VERSE || 18 ||
The distance in yojana of the place of observation from the bhūmadhyarekhā to the east or west is to be determined. This number is multiplied by the mean gati [in lipti] of all the planets and divided by the circumference, svadeśabhūparidhi obtained earlier. This is subtracted from the mean values of the respective planets, if svadeśa, the place of observation, is to the east, or added [if it is] to the west. This is the correction [called] yojanasanskāra.

Now the procedure for getting all the mean planets at midnight of the iṣṭakāla desired date.

VERSE || 19 ||
One has to get the time interval in ghaḷige vighaḷige, ahead of or lagging behind, from midnight; this time interval is multiplied by the madhya gati (mean rate of motion) in lipti, vilipti and divided by 60. If the iṣṭakāla (time of interest) is before midnight, the values in [lipti, vilipti] have to be subtracted; if it is after midnight [they have] to be added. The mean positions of all planets are now available for the desired time.

This completes the first chapter called Grahamadhyādhikāra of the book called Gaṇitagannaḍi, a commentary of Vārṣiktantra in the language of Karṇāṭa written by Śaṅkaranārāyaṇa Jyōtiṣi, who, is like Garuda (mythological enemy of snakes, the Brahminy kite) to snake-like ignorant astronomers, and who, akin to a full moon for the ocean of nectar [and] of Bṛhaspati - like Dēmaṇa, an eminent astronomer and a resident of Śṛṅgapura.

5 SPHUȚĀDHIKARA – TRANSLATION

SECOND CHAPTER Grahasphuṭādhikāra, getting the true position of planets.

VERSE || 1 ||
Ravi, the sun, is the foremost of all planets is reckoned as the śīghrocca for Guru, Kuja and Śani [for calculations from their] mean positions [which are known]. For Budha and Śukra the mean Sun (Ravi) is the mean [position] and the śīghrocca are themselves.

VERSE || 2 ||
The śīghrocca was told first; now mandoncā is being told. For the sun it is 78 (vasvādri), for Maṅgala, 130 (khaviśva), for Budha, 221 (rūpākṛti), for Guru, 172 (dvadrindavah), for Śukra, 80 (khāṣṭa) and for Śani, 237 (agāgnidasrāḥ). This is
obtained from the *mandocca bhagaṇas* [number of revolutions of the apogee, *mandocca*] stated in the *Sūryasiddhānta* in verses (I: 41 and 42) starting with “prāggate sūryamandasya” up to “gognayaḥ sani mandasya”, [these numbers are] multiplied by the number of years up to the desired year, and divided by the number of years in a kalpa. The current *mandocca* will be deficient by a few liptis from the date provided by Ācārya and one bhāgi has been added to account for this as Dhruva (constants).

**VERSE || 3 ||**

*Kendra* of a planet is obtained in *raṣi* [and its subunits] after subtracting the śīghrocca or *mandocca* from the mean planet. If the *kendra* is *tulādi* (starting with tulā, the angle is between 180 and 360 degrees) the calculated *śīghrabhujaphala* or *mandabhujaphala* should be added to the mean planet. If the *kendra* is *meśādi* (the angle is between 0 and 180 degrees) it should be subtracted. Later the method of getting the *śīghraphala* will be told [where] the *śīghrahara* 10 [vyomendavaḥ] should be added to *koṭiphala*, if *śīghrkendra* is *mrigādi* and subtracted if it is *karkyādi*.

**VERSE || 4 ||**

Now the procedure to get *bhuja* and *koṭi.* (In a right angled triangle, *bhuja* is the opposite side of the right-triangle and *koṭi* is the adjacent side of the right-triangle). In the odd quadrant *Bhujā* is determined by the current angle. *Koṭi* is (yet to be) covered. In the even (yugma) quadrant it is the opposite of this. That means - the angle to be covered determines the *bāhu* and the angle covered determines the *koṭi*. The *bhuja* and *koṭi* are for three rāṣis (90 deg). For 12 rāṣis there are four padas; there are two odd (oja) quadrants. For rāṣis 0, 1 and 2 are the same as for rāṣis 6, 7 and 8. Here *bhuja* is determined by angle covered and *koṭi* by the angle yet to be covered. For rāṣis 3, 4 and 5 and also for 9, 10, 11 which are even quadrants *koṭi* is determined by angle covered and *bhuja* by angle to be covered. Thus the *bhuja* and *koṭi* (found) for three rāṣis repeat for the others. From *bhuja*, *koṭi* can be determined by subtracting by 3 rāṣis.

(* We are thankful to the anonymous referee for pointing out the confusion in the original work itself. The corrections as per convention have been incorporated here.)

**VERSE || 5 ||**

Now to get the R sine for *bhuja* and *koṭi*: The rāṣi number is multiplied by 30 and added to bhāgi [degrees], divide this total [in degrees] bhāgi by 10. The quotient is the number of the *khaṅḍajīvā* covered all ready. The corresponding jīvā is written down. The value of the next *khaṅḍaj jīvā* is divided by 10 and multiplied by the
remainder whose \(\text{lipti}\) and \(\text{vilipti}\) have been converted to \(\text{bhāga}\) and added back to the \(\text{bhāga}\) value. The result (quotient) is added to the earlier obtained \(\text{jīvā}\). The remainder (in this step) is multiplied by 60 and divided by 10, converted to \(\text{lipti}\), \(\text{vilipti}\) and added to the \(\text{jīvā}\). This is the \(\text{jīvā}\) or \(\text{koṭi}\) derived for the desired angle. It should be noted that this is in [units of] \(\text{bhāgādi}\) (degrees).

**VERSE || 6 ||**

The nine \(\text{khaṅdas}\) of the \(\text{jīvās}\), (expressed in \(\text{bhūtasaṅkhya}\)) in the direct order are stated:

\[
21 \mid 20 \mid 19 \mid 17 \mid 15 \mid 12 \mid 9 \mid 5 \mid 2
\]

and

\[
2 \mid 5 \mid 9 \mid 12 \mid 15 \mid 17 \mid 19 \mid 20 \mid 21
\]

**VERSE || 7 ||**

The successive \(\text{fyākhaṅdas}\) are added to get the \(\text{piṅdkrtajīvā}\). They are 21, 41, 60, 77, 92, 104, 113, 118, and 120.

The \(\text{utkramapīṇḍas}\) are also provided. They are 2, 7, 16, 28, 43, 60, 79, 99, and 120.

**VERSE || 8 ||**

The \(\text{mandacheda}\) [divisors to get \(\text{mandaphala}\)] is being told [in words]. (\(\text{vyomāgnidanta}\)) 3230, (\(\text{śikhirupāśakra}\)) 1413, 603, (\(\text{purāmbarāṅga}\),1510, (\(\text{digarthacandra}\)) 1371, (\(\text{rūpāgaviśva}\)) 3769 (\(\text{aṅkarasādrirāma}\)) and 923 (\(\text{tripakṣaranḍhra}\)), for the planetary bodies starting from the sun (Ravi). These are the values of the divisors [for getting the \(\text{mandaphala}\)].

**VERSE || 9 ||**

To get the correction for the instant, \(R\) sine is multiplied by 60 and added to \(\text{lipti}\). The sum is divided by the numbers 90 and others for the respective planets as prescribed in the verse starting with \(\text{khaṅkaiḥ}\). (2.9) The result is added to the numbers mentioned earlier as \(\text{vyomāgnidanta}\) and so on \{\((490 \text{ (khaṭāna)}, 300 \text{ (viyad abhrarāma)}, 70 \text{ (khaśva)}, 170 \text{ (khaśailendu)}, 21 \text{ (indupakṣa)}, 380 \text{ (khaśtāgni)})\} to get the corrected divisor \(\text{sphuṭamandacheda}\).

Now the \(\text{śīghra cheda}\) for the five planets starting from Kuja.

**VERSE || 10 ||**

1110 (\(\text{digīśvara}\)), 1956 (\(\text{tarkaśarāṅkacandra}\)), 3651 (\(\text{koarthāṅgarāma}\)), 993 (\(\text{jvalanāṅkananda}\)), 6562 (\(\text{dvāṅgaiṣutarka}\)). These \(\text{śīghrachedas}\) have been de-
vised similar to *mandacheda* as specified in [Sūrya]siddhānta.

**VERSE || 11 ||**

To get the *mandaphala* and *śīghraphala*, [one needs] *bhuaphala* and *koṭiphala*. The *bhuja* and *koṭijīvas* are kept in two places; multiply them by 60 and add to the *litpi* in lower place. Then they are divided by the respective *manda cheda* and *śīghra cheda* to get *bhuaphala* and *koṭiphala* in degrees etc. As stated in the verse the *manda* arises because of only *bhuaphala* and therefore there is no need of *koṭiphala* for the *manda* correction. The *jyā* of *bhuja* is multiplied by 60 and added to the *lipti* part and divided by the divisors as specified by *vyomāgni* etc. which are made true by correcting with *khankaih* etc., for the planets beginning with the Sun for the respective planets. The result in *bhāga* units [degrees] is the [first correction] *mandaphala*. This is negative if the *kendra* obtained by subtracting mean from *mandocca* is in *karkyādi*, (starting from karka, between 0 and 180) positive if it is *tulādi* (between 180 and 360). This gives the [longitude] after the [first] *manda* correction, *mandasphuṭa*.

**VERSES || 12 ||, || 13 || AND || 14 ||**

The mean motion *madhyagati* of the planets are being told in *lipti*, *vilipti*. For Ravi it is 59|8, for the moon 790|35 for Kuja 31|26, for Budha 245|32, for Guru 5|0, for Śukra 96|8, for Śani 2|0, for Rāhu 3|11, for *candrocca* 6|41. While making the *mandasphuṭa* correction, for getting the *𝑅* sine, the *khaṅda* corresponding to the *eṣya* [to be covered part], is multiplied by the *madhyagati* in *lipti*, *vilipti* and multiplied by 6 (*rasaghna*) and divided by the appropriate divisor and added if it is *karkyādi*, subtracted for *makarādi*. This gives *mandasphuṭagati*.

The derivation of the (mean motion) *madhyagati* is done by dividing the *bhagana* (number of revolutions) as specified in *Sūryasiddhānta* by the *bhūsāvanadina* (number of days). It is [done] like this. Number of revolutions of Ravi is 4320000. The number of *sāvana* days are 1577917828. When this is divided [by number of revolutions] we get 0 *rāśi*, 0 *bhāga*, *lipti* 59 and *vilipti* 8. This is done for all planets. The meaning of *madhyagati* is the number of *liptis* covered in a day.

Although the procedure for *mandasphuṭa* is explained, I am summarising it again. It is like this. After obtaining the mean planets, take the difference with respective *mandoccas*, get the *R* sine by using the rule as *bhāgāstayoh kenduhṛta*, (verse number 2.5 above) multiply by 60 and add the *lipti*. Consider the numbers specified by the verse *khāṅka* and so on, added to the original divisors specified by *vyomāgni*, and divide the *jyā*, which is already multiplied by 60 by the revised divisor, and take the result in *bhāga*. When the mean planet is corrected with this, by subtraction, if it is *meśādi*, and by addition, if it is *tulādi*, the *mandasphuṭa*
is obtained. Here it should be remembered that the sun and the moon are *sphuṭa* by this correction. The five planets *Kujādi* will be *spaṣṭa* after the two corrections, namely, *manda* and *śīghra*. Thus after completing the explanation for *manda*, I proceed to explain *śīghraphala*.

**VERSE || 15 ||**

Now, the procedure for *śīghraphala* for the planets starting from *Kuja*. The *śīghraocca* subtracted from the *mandasphuṭa* corrected planet is the *kendra*. Both the *bhuja* (*R* sine) and *koṭi* (*R* cosine) are obtained. As per the verse *do koṭih āve kharasaṅh nihatvāt*, (verse 2.11 above) the *bhujājīva* and *koṭijīva* are multiplied by 60, the remainder is added back. These are divided by the appropriate divisors as specified by the verse starting with *digiśvara*. (verse 2.10 above) The result from *bhuja* is *bhujaphala*; the result from *koṭi* is *koṭiphala*. *Vyomendu* 10, is the *śīghrahara*. The *koṭiphala* obtained is added to or subtracted from this *hara* (10) as per *mrigādi* or *karkādi*. The square of this sum or difference is obtained. Next, as stated by *dorjyaphala varga yogāt*, the square of *bhujaphala* is obtained. The two squares are added and the square root is the *phala* called the *calabāṇa*.

**VERSE || 16 ||**

The *bhujaphala* is multiplied by the *trijya* 120, divided by *calabāṇa*. The inverse sine, *cāpa*, of this is the *śīghraphala* in *bhāga* (degrees). For *Kuja*, *Budha*, *Guru*, *Śukra* and *Śani* this is applied as positive or negative as mentioned earlier. Thus we get all the true planets.

**VERSE || 17 ||**

The procedure to get the inverse sine, *cāpa* (the arc of the angle). The arc has to be obtained (from the *jyā*). Subtract as many *khaṇḍajīvās* as possible from the *jīvā*. Keep aside the number of *khaṇḍajīvās* subtracted. The remainder is multiplied by 10 and divided by the *khaṇḍajīvā* which is the *khaṇḍa* which comes after the subtracted ones. When this is added to 10 times the number (of *khaṇḍajīvās*) kept aside [earlier], that (sum) is the desired arc in (degrees). The result is the inverse sine, *cāpa*.

**VERSE || 18 ||**

The *gati* of the *mandasphuṭa* is subtracted from the *gati* of the difference of *śīghraocca* and *graha*. What remains is multiplied by the difference between the *śīghrahara* and the *calabāṇa* as per the [rule of] *catuthpratīnyāya*. This is divided by the *calabāṇa* and the result in *liptādi* [sundivisions of arcminutes] is added to the *mandasphuṭa* if the *bāṇa* is greater than the *hara*, and subtracted from it if the *bāṇa* is
less than the *hara*. The result is the *sphuṭagati* (true rate of motion). If the (earlier) result is greater than the *mandagati*, the *mandagati* is subtracted from the (earlier) result, and what remains is the *vakragati* (retrograde rate of motion).

VERSE || 19 ||

The $R\sin e$ of the sun (Ravi) is converted to *lipti* as per the verse *uṣṇām śu dorjaphalam* and divided by 27. The result in *liptis* is added to or subtracted from the moon, *Candra*, as per the correction to the sun. If the *bhujaphala* is positive it is added to the moon. If it is negative for the sun it should be subtracted from the moon also. That gives *Ravibhujasanskrtacandra* - moon corrected for *Ravibhuja*. This correction is to be done for all planets as stated in the [Sūrya]siddhānta. But for all the others it is quite small and therefore I told it specifically for the moon. This correction should be done for all planets.

VERSE || 20 || SŪRYASIDDHĀNTA (II - 46)

This is as per the statement in [Sūrya]siddhānta - the *gati* of planets should be multiplied by *Ravibhujaphala* in *kala* (arc minutes) and divided by *cakralipti*, that is 21600; the result is positive or negative as is the case for the sun. The mean *gati* of the moon is 791 *lipti*. Adripakṣa, 27 is the result when 21600 is divided by this. Therefore I made the rule for division by 27.

This completes the second chapter called *Grahasphuṭādhikāra* of the book called *Ganitagannaḍi*, a commentary of *Vārṣiktantra* in the language of Karṇāṭa written by Śaṅkaranārāyaṇa Iyōṭiṣi, who, to the ignorant astronomers, is like Garuda to snakes and who, akin to a full moon for the ocean of nectar [and] of Bṛhaspati – like Dēmaṇa, an eminent astronomer and a resident of Śṛṅgapura.

6 TEXTS

We give the text from the original palm leaf manuscript for the second half of first chapter and the second chapter (covered in this paper) which has the verses in Sanskrit and commentary in Kannada. As mentioned earlier the script is *Nandināgarī* and here we have put both languages in Kannada script.

CONTINUATION OF CHAPTER 1

Here we give the text from the original palm leaf manuscript for the second half of first chapter and the second chapter (covered in this paper) which has the verses in Sanskrit and commentary in Kannada. As mentioned earlier the script is *Nandināgarī* and here we have put both languages in Kannada script.
MEAN AND TRUE POSITIONS OF PLANETS

HISTORY OF SCIENCE IN SOUTH ASIA 9 (2021) 232–272
ರಿಂದ ಬಂದದು ಲಿಪಿತ | ವಿಲಿಪಿತಯಂ ತಹುದು | ಇದಂ ಮುಂನಿನ ಪದದೊಳಗೆ ಕ್ರಮದಿಂದ ಕಳೆಯಲು ಉಳಿದದು «ಾ–ಾದಿ­ಾದ ಮ¦ಾ್ಯದಿತ್ಯನಹನು | ಆ «ಾಗಿಯ ³ಾ್ಥನಮಂ 30 ರಿಂದೆತಿ್ತ ಬಂದ ಲಬ್ಧವಂ ಮೇಲೆ ಇರಿಸಲು ಅದೇ ®ಾಶಿ | ಶೇಷವೇ «ಾಗಿ | ಮೊದಲವೇ ಲಿಪಿತ ವಿಲಿಪಿತ | ಇಂತು ®ಾಶಿ «ಾಗಿ ಲಿಪಿತ ವಿಲಿ¨ಾ್ತತ್ಮಕ°ಾಗಿ £ಾ ನೋಡುವ ದಿನದ ಮಧ್ಯ®ಾತೆ್ರಗೆ ಬಂದ ಮಧ್ಯಚಂದ್ರನಹನು ||

ಇಲಿಲ ದಿನ 1ಕೆ್ಕ ಮಧ್ಯಗತಿ ಲಿಪಿತ 59 ವಿಲಿಪಿತ 8 | ಈ ಲೆಕ್ಕದಲಿ್ಲ 70 ದಿನಕೆ್ಕ ವೊಂದು «ಾಗಿ ಕಡಮೆಯಂ ಯಹುದೆಂಬುದೀಗ ಗಣಿತ °ಾಸನೆ ||

ಅಂ±ಾದಿಕೇಂದೋ� ಪದಮಕರ್ನಿಘ್ನಂ ³ಾ್ವ²ಾ್ಟಂಗ«ಾಗೇನ ಪದೇನ ಯುಕ್ತಂ || 13 ||

ಪದಂ ಪದವನು | ಅಕರ್ನಿಘ್ನಂ ಯೆಂದು 12 ರಿಂಗುಣಿಸಿ ³ಾ್ವ²ಾ್ಟಂಗ«ಾಗೇನ ಯುಕ್ತಂ

ಯೆಂದು | ಆ ಹನೆರಡರಿಂದಧಿಕ°ಾಗಿದ್ದರೆ 12 ರಿಂದೆತಿ್ತ ಬಂದವಂ ಮೇಲೆ ಕೂಡಿಕೊಂಡು ಮೇಲಣ ಪ್ರತಿಯಂ ನಿಧಿಪಕ್ಷನೇತೆ್ರŒಃ

ಪದವಂ ಕೂಡಿದರೆ «ಾ–ಾದಿಯಹುದು | ಅವಂ 30 ರಿಂದೆತಿ್ತ ಬಂದವು ಲಿಪಿತ ವಿಲಿಪಿತಯಂ ತಂದುಕೊಂಬುದು | ಇಂತು

ಬಂದ ®ಾ±ಾ್ಯದಿಯಂ ಕುಜನ ವಷರ್ಧು್ರವದೊಳು ಕೂಡಲು ಮಧ್ಯಕುಜನಹನು ||

ಇಲಿಲ ಪದೇನ ಯುಕ್ತಂ

ಬುಧ ಶೀಘೊ್ರೕಚ್ಚವಂ ತಹರೆ ||

ಜ್ಞಃ •ಾಗಿ್ನಭಿಃ ಯೆಂದು ತೃತೀ­ಾ ಬಹುವಚ§ಾಂತ°ಾದ ಛೇದವನೆ ಹೇಳಿ ಗುಣಕವ ಪೇಳಿದದಿ್ದಲ್ಲ°ಾಗಿ ಪ್ರಕರಣಬಲದಿಂದ ಕುಜಗೆ ಪೇಳಿದ ಕೃತ ಯೆಂಬುದೇ ಗುಣಕವೆಂದು | ಪದವಂ
MEAN AND TRUE POSITIONS OF PLANETS

HISTORY OF SCIENCE IN SOUTH ASIA 9 (2021) 232–272
ಬೇಕಾಗಿದ್ದ ವಾಸ್ತುವಿದ್ಯೆ ಕೃತಿಪುರಾಣಾಕಾರ ಜಾಗತನ ತಾ | 
ವಿಜಯಪುರಾಣ ವಿಜಯಾಚಾರ್ಯ ಕೃತಿಪುರಾಣಾಕಾರ | || (1-59)

ಯೋಜನಾ ಶುಭದೃಢವಾಗಿದ್ದೆಂದರೆ ಮೇರು ಭೂಮಿ ಅಡ್ಡ ಅಡ್ಡಗೊಳಿಸಿದೆ | || 
ಗುಣಗೊಳಿಸಿದ್ದು ಮೇರು ಭೂಮಿಯಾಗಿ ಅಡ್ಡ ಅಡ್ಡಗೊಳಿಸಿದೆ | || 
ಕೇಂಪುರಾಣ ಪ್ರಯೋಗದಲ್ಲಿ ಮೇರು ಭೂಮಿಯಾಗಿ ಅಡ್ಡ ಅಡ್ಡಗೊಳಿಸಿದೆ | || 
ಅಡ್ಡದ ಮೇರು ಭೂಮಿಯಾಗಿದ್ದರೆ ಸಾಮುದ್ಯ ಗೊಳಿಸಿದೆ | || 

ಯೋಜನೆಯಾಗಿ ಅಡ್ಡ ಅಡ್ಡಗೊಳಿಸಿದೆ | || 
ಸ್ವಕೀಯ ಅಂತರ ಗುಣಗೊಳಿಸಿದೆ | || 
ಕೃತಿಪುರಾಣ ವಿಜಯ ಗುರುಭೋದ್ಯಮ ನಮಸ್ತಕೇ | || 
ಹಿಮನದ್ಧಾರಿತ ಪ್ರಾಯೋಗಿಕ ಕೃತಿಪುರಾಣಾಕಾರ | || 

c


SECOND CHAPTER

ಇಂತು ಶೃಂಗಪುರ್ರಾಸ ದೇವಣಾಳ ದೇವಣಾಳ | 
ಆದೊಟ್ಟಿರುವ ರಾಜಪುರ್ಣಕಕ್ಕಡ ಶ್ರೀಮಂಗಳದ್ಯಗ ಆಧಾರ | || 
ಶ್ರೀಮಂಗಳದ್ಯಗದಲ್ಲಿ ಶ್ರೀಮಂಗಳದ್ಯಗದಲ್ಲಿ | ||
MEAN AND TRUE POSITIONS OF PLANETS

HISTORY OF SCIENCE IN SOUTH ASIA 9 (2021) 232–272
ಭುಜೆ ಇದ್ದರೆ ಕೋಟಿ | ಕೋಟಿಯಿದ್ದರೆ ಮೂರು ಆರು ವಿಶೇಷಗಳು ಶೋಧಿಸಲು ಅದೇ ಮತೊ್ತಂದಹುದು | ಭುಜೆ ಇದ್ದರೆ ಕೋಟಿ | ಕೋಟಿ ಮೂರು ಆರು ವಿಶೇಷಗಳು ಶೋಧಿಸಿ ಕೂಡಿ | ಮೂರು ಆರು ವಿಶೇಷಗಳು ಕ್ರಮವಾಗಿ ಪಾಲು ಹೊಂದಿರುತ್ತದೆ.  ಅದರ ಮೂರು ಆರು ವಿಶೇಷಗಳು ಶೋಧಿಸಿ ಕೂಡಿ | ಮೂರು ಆರು ವಿಶೇಷಗಳು ಕ್ರಮವಾಗಿ ಪಾಲು ಹೊಂದಿರುತ್ತದೆ.  ಅದರ ಮೂರು ಆರು ವಿಶೇಷಗಳು ಶೋಧಿಸಿ ಕೂಡಿ.
MEAN AND TRUE POSITIONS OF PLANETS

2.8

2.8

2.9

2.10

2.11

HISTORY OF SCIENCE IN SOUTH ASIA 9 (2021) 232–272
ಮಧ್ಯಗತಿಲಿರ್ಪಿತ ವಿಲಿಪಿತ “ಾಫಾಾದಾಯಗರಡೇ ಗಾಶ್ಚ |
ಇಂದೋಃ ಖಗೋಾವಃ ಶರವಹ್ನಯಶ್ಚ ಒೂೕಣೀಗುಣಾಃ ಷಡ್ಯಮಾಂ ಕುಜಸ್ಯ || 2.12 ||
ಬುಧಸ್ಯ ªಾಣಾಬಿರವಟರವ್ಚಾ ಬೃಹಸ್ಪತೇಃ ಪಂಚನಭಶ್ಚ |
ಭೃಗೋ ರಾಂವರಸವಃ ಶನೇವೌವರ್ದ ವಿಯಚ್ಚ ಈಶ್ವರಶ್ಚ || 2.13 ||
ಷಟ್ಚಂದ್ರವೇವರ ವಿಧು ತುಂಗ ಭುಕಿ್ತಭುರ್ಜೈಷ್ಯಖಂಡೇನ ಹೆ ರಸ–ಾನ |
ಛೇದೈವಿರ್ಭಾಗ ಯೆಂದು ತಂಮ ಸು್ಫಟ ಮಂದ ಹರದಿಂದ «ಾಗಿಸಿ ಬಂದ ಲಿ¨ಾತದಿ |
ಮೇಂದ ಕೇಂದ್ರವನಲ್ಲಿ ಕಳತುದು, ಕುಜರಿಗೆ 31 | 26 ಮಾಸಿಗ 245 | 32 ಹಗಿ 5 | 0 ಶುಕ್ರಗೆ 96 | 8 ಶನಿಗೆ 2 | 0 ¨ಾಹುವಿಗೆ 3 | 11 ಚಂದೊ್ರೕಚ್ಚಕೆ 6 | 41
ಮಂದಸು್ಫಟದ ಉತ್ಪತ್ತಿಯೆಂದರೆ | ಶಿ್ರೕಸೂಯರ್ಸಿಧಂತದಲ್ಲಿರುವ ತಂಮ ಭಗಣಂಗಳಂ ಭೂವಾವನದಿನಗಳಿಂದ ಭಗಣಾದಿ ಫಲವಹುದು | ಅದೇ ಮಧ್ಯಗತಿ |
ಅದೆಂತೆಂದರೆ | ರವಿ ಭಗಣ 4320000 ಇತಿ ³ಾವನದಿನ 1577917828 ಇತಿ ಮೂಗ ನಂದ ಪ್ರತಿ 59, ಮಂದ ಮಂದ, 0, ಮೂರೆ, 60 ಮಂದ ಕಮರ್ದಿಂದ ಮುಂದೆ ಸಂಸ್ಕರಿಸಲು ಮಂದಸು್ಫಟಗತಿಯಹುದು | ಇಲ್ಲ ರವಿಚಂದ್ರರಿಬ್ಬಲು ಈ ಮಂದ ಕಮರ್ದಿಂದಲೇ ಸು್ಫಟವಹರೆಂದರೂ ಮುಂದೆ ಹೊಳುತಿ¥ಾ್ಧನು |
MEAN AND TRUE POSITIONS OF PLANETS

HISTORY OF SCIENCE IN SOUTH ASIA 9 (2021) 232–272
The authors are grateful to the referees for very critical comments which have greatly enhanced the conceptual clarity. One of the authors (SJ) acknowledges the help by INTACH, Bengaluru and Dr Keladi Gunda Jois for a great help with the manuscripts, Sri Śankara Advaita Śodhana Kendra in Śringeri, for getting the scans of the manuscripts. Discussions with Prof. M. D. Srinivas, Dr Venketeswara R. Pai, Dr Uma S. K., Dr K. R. Ganesha and Prof. S. Balachandra Rao are gratefully acknowledged. The meters and typographical corrections for the verses were kindly scrutinised by B. S. Shubha and A. Muralidhara.
SECONDARY LITERATURE


—— (2008), *Karanaakutūḥalam of Bhāskarācārya II. An English Translation with Mathematical Explanation, Derivations, Examples, Tables and Diagrams* (New Delhi: Indian National Science Academy); Reprinted from *IJHS*, 42.1–2 (2007); 43.1 & 3 (2008).

Bapu Deva Sastri (1861) (ed.), *Translation of the Sūrya Siddhānta and of the Siddhānta Śiro-mani by the late Lancelot Wilkinson* (Calcutta: Baptist Mission Press), arK: arK:/13960/t77t69d4g.

Chatterjee, B. (1981), *Śisyaḍhīvṛddhida Tantra of Lalla with the Commentary of Mallikārjuna* (New Delhi: Indian National Science Academy), arK: arK:/13960/t3gz2x556; vol. 2: http://n2t.net/ark:/13960/t17m8w72b.


Mahesh, K. and Seetharama Javagal (2020), *Karanaabharaṇam, a Commentary on Karana-prakāśa of Brahmadeva by Śaṅkaranārāyaṇa, the Son of Śrīgapurī Dēmaṇa Joyisa* (Tirupati: Rashtriya Sanskrit Vidyapeetha).


Please write to wujastyk@ualberta.ca to file bugs/problem reports, feature requests and to get involved.

The History of Science in South Asia • Department of History and Classics, 2–81 HM Tory Building, University of Alberta, Edmonton, AB, T6G 2H4, Canada.