लघुमानस
मञ्जुलाचार्य (Laghumānasa)

By Arun Kumar Upadhyay as per commentary of Prof. Kripashankar Shukla, published by Indian national Science Academy, New Delhi-2, in 1990

अथ ध्रुवकनिरूपणाधिकारः प्रथमः (Chapter 1-Dhruvakas or constant parameters)

ग्रन्थकर्तृपरिचयपूर्वकं ग्रन्थप्रयोजनाख्यानम् (Introduction, author, purpose of book)

प्रकाशादित्यवत् ख्यातो भारद्वाजो द्विजोत्तमः। लघ्वपूर्वस्फुटोपायं वक्ष्येऽन्यल्लघुमानसम्॥१॥

I, (Mañjulāchārya), famous as the Sun in Prakāśa (pattana), born in Bharadvāja Gotra, best among the Brāhmaṇas, set forth another work, entitled Laghumānasa, which is small and contains brief and unprecedented methods of planetary computation.

Note-Prakāśapattana was 80 yojanas east of Ujjain and height of equinoctical midday shadow there was 5 ¾ angulas. (Mallikārjuna Sūri's commentary on Lalla's Śiṣyadhīvṛddhida tantra). That gives the location $25^0$36'N and longitude $85^0$6' E. (circumference of earth here is taken as 3300 yojanas as taken by Lalla). This is just north of Patna. On north bank of Gangā river, there could be light house, called Prakāśapattana, now translated as Hazipur.

ग्रन्थप्रयोगविधानम् (Computation of planets, preliminary instructions)

चैत्रादौ वारसंक्रान्तितिथ्यर्केन्दूच्चसध्रुवान्। ज्ञावाऽन्यांश्चार्कवर्षादावाजन्म गणयेत्ततः॥२॥

Knowing the week-day, the samkrānti tithi, the position of the Sun, Moon, the apogees (Ucchas) of planets for the beginning of Chaitra (of the epochal year) together with the epochal Śaka year (known as Dhruva) as well as the other elements (such as the position of the planets, their ascending nodes, the precession of the equinoxes, etc.) for the beginning of the (next mean) solar year, one should calculate the positions of the planets throughout one's life (i.e., for one hundred years).

ग्रन्थकारनिबद्ध पूर्वध्रुवकाः (Epochal positions compled by author)

कृतशरवसु (८५४)मितशाके चैत्रादौ सौरिवारमध्याह्ने।

राश्यादिरजनृपार्का (११रा. १६°१२') रविइन्दुर्भवधृतिद्वियमाः।(११रा.१९°२२')॥१॥

सूर्यान्मन्दोच्चांशा वसुतुरगाः (७८°) पर्वतास्तु सत्र्यंशाः (७ १/३°)।

स्वररवयः (१२७०) खाकृतयो (२२०°) द्विनगभुवो (१७२°) ऽशीति (८०°) रद्रिजिनाः(२४७°) ॥२॥

On saturday noon, the beginning of Chaitra, Śaka year 854, (the positions of the Sun, Moon, and the apogees of the planets are as follows-

Sun $11^s16^0$12'

Moon $11^s18^0$22'

Apogee of:

Sun 78^0 or 2s 18^0

Moon 7 1/3 ^{0} or $0^s7^0$20'

Mars 127^0 or 4^s 7^0

Apogee of:

Mercury 220^0 or 7^s10^0

Jupiter 172^0 or 5^s22^0

Venus 80^0 or 2^s 20^0

Satun 247^0 or 8^s 7^0

द्व्युत्कृत्तिखानि (२रा,२६°०') युगोत्कृतिकराब्धयः (४रा.२६°४२') खाष्टनव (०रा.८°९')
दशत्रिसुराः(१०रा.३°३३')।
गोऽष्टाविंशतितानाः (९रा. २८°४९') कुजादयस्सूर्यभगणान्ते॥३॥
संक्रान्तितिथिध्रुवकाः शक्रा(१४) वसुनवरसेषवो(८रा.९°५६') राहोः।
कृतयमवसुरसदसका(४,२,८,६,१०) दशा(१०)हताः शेषपातांशाः॥४॥
अयनचलनाष्शडंशाः पञ्चाशल्लिप्तिका (६°५०')स्तथकैकाः(१')॥
प्रत्यब्दं तत्सहितो रविरुत्तरविषुवदादिः स्यात्॥५॥

Positions at the end of mean solar year (in Śaka 854)

And at the completion of the Sun's revolution (in Śaka 854) (the position of the planets and their ascending nodes etc., are as follows):

Mars	2^{s}26^{0}00'
Śīghroccha of Mercury	4^{s}26^{0}42'
Jupiter	0^{s}8^{0}9'
Śīghroccha of Venus	10^{s}3^{0}33'
Saturn	9^{s}28^{0}49'

Sankrānti tithi (i.e. tithi of Meṣa-sankrānti day) 14

Ascending node of:

Moon	8^s 9^{0}56'
Mars	40^0
Mercury	20^0
Jupiter	80^0
Venus	60^0
Saturn	100^0

Ayana-chalana or precession of the equinoxes 6^{0}50'

Rate of ayana-chalana 1' per year

The longitudes of Sun etc. are increased by ayana-chalana are to be reckoned from the vernal equinox (lit. north viṣuvat).

वाराणसी प्रति (१-५) स्थाने निम्नलिखित ९ श्लोकाः-
कृतेष्विभमिते शाके मध्याह्ने रविवासरे। चैत्रादौ ध्रुवकान् वक्ष्ये रविचन्द्रेन्दुतुङ्गजान्॥१॥
राश्याद्यर्कध्रुवो रुद्रा नृपार्को खमनु क्रमात्। इन्दोर्भवाश्च धृतयो द्वियमाः खमिति क्रमात्॥२॥
उच्चस्य ध्रुव(कः) शून्यं सत्र्यंशा अथ पर्वताः। कुजस्य द्व्युत्कृतिर्खानि युगोत्कृतिकराब्धयः॥३॥
ज्ञस्य खाष्टनवेज्यस्य कवेर्दर्शगुणाः सुराः। गोऽष्टाविंशतितानाश्च ध्रुवः शनैश्चरो भवेत्॥४॥
वसवो युगषड्बाणा विलोमाःश्चन्द्रपातजाः। रविवर्षमुखे भौमपूर्वाणां ध्रुवका अमी॥५॥
रवेर्नन्देषवोऽष्टौ च खगोशैलाः शराग्नयः। चन्द्रस्य च तदुच्चस्य रसा रूपाब्धयस्तथा॥६॥
कुजस्य भुक्तिः क्रमशो रूपाग्नि अथ षड्यमौ। पञ्चाब्धिपक्षाश्च यमाग्नयो भुक्तिर्बुधस्य च॥७॥
पञ्चेज्यस्य च षण्णन्दा अष्टौ च भृगुनन्दनः। शनेश्च दस्रौ पातस्य गन्ता रुद्रा गतिर्भवेत्॥८॥
गजाश्वाश्च स्वरादित्या खाकृतिर्द्धिनगेन्दवः। खाष्टौ सप्तजिना रव्याद्युच्चांसस्तत्र वर्जिताः॥९॥

Rationale by Sūryadeva Yajvā based on Āryabhaṭīya of Āryabhaṭa-1, Brāhma-sphuṭa-siddhānta of Brahmagupta and Sūrya-siddhānta.

Revolutions of the planets

Planet	Revs. in a yuga	Revs. in a kalpa	Taken from
Sun	43,20,000		Ā
Moon	5,77,53,336		Ā

Mars 22,96,824 Ā
Śīghroccha of Mercury 1,79,37,020 Ā
Jupiter 3,64,224 Ā
Śīghroccha of Venus 70,22,376 SūSi
Saturn 14,65,67,298 BrSpSi

Sūryadeva Yajvā has shown that the Bīja corrections also have been applied as followed by traditional Āryabhaṭa school-

Moon -25/235 min. per year since Śaka 444
Śīghroccha of Mercury +430/235 ,, ,, Śaka 420
Jupiter -50/235 ,, ,, ,,, Śaka 444
Mars (as per Bhaṭṭotpala) 36' +[(1/4)' per year since Śaka 587]

Sūrya-siddhānta does not prescribe any Bīja correction, so no correction has been applied to Śīghroccha of Venus. For Saturn values also taken from Brāhma-sphuṭa-siddhānta, no Bīja correction has been applied.

However, Yallaya commentary uses another Bīja correction from the same Āryabhaṭa school-

Moon -25/250 min. per year since Śaka 421
Mars +48/250 ,, ,, ,,,
Śīghroccha of Mercury + 430/250 ,, ,, ,,,
Jupiter -47/250 ,, ,, ,,,
Moon's apogee -114/250 ,, ,, ,,,
Moon's ascending node -96/250 ,, ,, ,,,

Apogee of planets-

Sun's apogee is same as in Āryabhaṭīya. Moon's apogee has been calculated from yuga-revolutions given in Āryabhaṭīya (viz. 488219) and applying Bīja correction prescribed by Bhaṭṭotpala, viz.

-(70' +1/2 min. per year since Śaka 587.

Mars' apogee is same as in Uttara-Khaṇḍakhādyaka, those of Mercury and Venus are as in Pūrva-Khaṇḍakhādyaka. Apogee of Jupiter is as per Brahmagupta by taking 855 as the number of revolutions in a Kalpa (432,00,00,000 years). Apogee of Saturn is Mañjula's own.

Ascending nodes of the planets- Ascending nodes of the planets Mars etc, are same as in Āryabhaṭīya and Khaṇḍakhādyaka. Moon's ascending node has been calculated from yuga-revolutions given in Āryabhaṭīya (viz. 232226) and applying traditional Bīja correction of the Āryabhaṭa school, viz. -96/235 min. per year since Śaka 444.

Mean position-

Number of years since beginning of Kalpa till start of Śaka (Śālivāhana in 78 AD) is 1,97,29,47,179. Sūrya-siddhānta deducts 1,70,64,000 years taken in creation after Kalpa start. Laghumānasa has adopte values of Āryabhaṭīya-

Solar months in a yuga 5,18,40,000
Lunar days in a yuga 1,60,30,00,000
Intercalary months in a yuga 15,93,336
Omitted lunar days (tithis) in a yuga 2,50,82,580
Civil days in a yuga 1,57,79,17,500

The initial constants stated by Mañjula were meant to be used for 100 years. After

100 years, they had to be computed afresh. Various commentators calculated initial constants for Chaitrādi noon for different Śakas as indicated -Praśastidhara 880, Sūryadeva Yajvā 1170, Parameśvara 1331, Makaranda 1400, Yallaya 1404, Mallikārjuna Sūri (assumption) 1100.

Samkrānti tithi- Praśastidhara has give 2 rules for that-

Approximate rule-The degrees to be traversed by the Sun from Chaitrādi up to the Meṣa-samkrānti gives the Samkrānti tithi.

Accurate rule-Find difference between sun and moon positions in minutes at noon before or after (Chaitrādi). Multiply that by Sun's daily motion and divided by difference of moon-sun motions. Add it to or substract it from the Sun's longitude, according as the Sun's longitude is greater or less than the Moon's longitude. Substract that from a circle (or 360^0); then multiply that by 100 and divide by 97; the quotient gives the Samkrānti tithi.

Rationale-Let longitudes of Sun and Moon at noon just before beginning of Chaitra be S, M,

S > M. Let S – M = D.

At start of Chaitra, D=0, so motion of Sun from that noon up to start of Chaitra

Therefore, Sun's longitude at beginning of Chaitra

= S +

= S' degrees, say.

Now the Sun's longitude at Meṣa-samkrānti = 360^0. Therefore,

Samkrānti tithi = =

= =

Hence the rule.

Sūryadeva Yajvā finds Samkrānti tithi for Śaka year 854 by converting adhimāsa-śeṣa afor end of Śaka year 854 into tithis. this is because adhimāsa-śeṣa converted int tithis is equal to number of tithis between Chaitrādi and Meṣa-samkrānti.

Ayana-chalana or precession of equinoxes-

Here, formula is ayana chalana = (Śaka year - 444) minutes.

Thus, for Mañjula's epoch, i.e. for Śaka 854,

ayanachalana = (854 – 444) minutes = 410' or 6^0 50'

Rate of precession = 1' per year.

In Bṛhanmānasa, Mañjula has given 199669 revolutions of equinox point in a kalpa (432 crore years). Mañjula has been quoted by Munīśvara in his commentary on Siddhānta-śiromaṇi of Bhāskara-2 and this verse is not in Laghumānasa, so it should be in Mañjula's other work Bṛhanmānasa, which is lost now-

निर्दिष्टोऽयनसन्धिश्चलनं तत्रैव सम्भवति। तद्भगणाः कल्पे स्युर्गोरसरसगोऽङ्कचन्द्रमिताः॥

This yields 59".9 as the annual rate of precession of the equinoxes. If precession of the equinoxes be assumed zero in Śaka 444, then its value in Śaka 854 will be

mins.

= 409'19" or $6^0$49'19"

Which is about $6^0$50' taken here.

These 5 verses giving initial conditions are not in anuṣṭup as rest of the book, but in āryā meter. This difference is for 2 purposes as per Sūryadeva Yajvā-

- This is only to be used for 100 years.

- When new constants are calculated for next epoch, they should be separated with a separate meter.

Thus, all the following commentators have given constants in āryā meter only.
इति लघुमानसे ध्रुवकनिरूपणाधिकारः प्रथमः॥
Thus ends chapter 1 about initial constants in Laghumānasa.
अथ मध्यमगत्याधिकारः द्वितीयः (Chapter II-Mean Motion)
वाराणसी प्रति-शाकः कृतेष्विभै(८५४) रूनो ध्रुवाब्दगणो भवेत्।
तत्रार्कवारसंक्रान्तितिथि रुद्रा(११) मिता भवेत्॥
ध्रुवाद्यब्दगणो दिग्(१०)घ्नस्स्वकीयाष्टांशसंयुतः। संक्रान्तितिथियुक्तोऽधः स्वषष्ट्यंशविवर्जितः॥३॥
त्रिंशच्छिन्नावशेषोनश्चैत्रादितिथिभिर्युतः। त्रिगुणाब्दगतर्तूनो द्युगणो ध्रुववासरात्॥४॥
Dyugaṇa-Multiply the number of years elapsed since epoch (Dhruvādi or Dhruvābdādi) by 10, then add it to one-eighth of itself, and then add the samkrānti tithi. Put down the result in 2 places, one below the other. In lower place, deduct 1/60 of itself and divide what remains by 30. Deduct the remainder of this division from the result put down at the upper place; to that add the number of tithis elapsed (since Chaitrādi); from that substract 3 times the number of years elapsed (since the epoch) and also the number of seasons elapsed (since the Chaitrādi of the current year); what is now obtained is the Dyugaṇa. This being divided by 7, the remainder counted from the day for which the epochal constants are computed gives the current day.
That is: Dyugaṇa = $10Y + 10Y/8 + S_1 - R + C_1 - 3Y - s$,
Where R is given by $(10Y + 10Y/8 + S_1)(1-1/60) = 30Q + R$
and Y = years elapsed since the epoch
S_1 = Samkrāti tithi, C_1 = Chaitrādi tithi
S = seasons elapsed since Chaitrādi.
Rationale-Let A be the Chaitrādi of the Dhruvābda, B the Chaitrādi occurring Y lunar years thereafter, C the Chaitrādi of the current year, and T the beginning of the tithi for which the Dyugaṇa is to be calculated.
A S B C S T
Let S be the beginning of the solar year falling after A, and Ś the beginning of the current solar year (occurring Y solar years after S).
There are approximately 354 civil days in a lunar or synodic year and 365 ¼ civil days in a solar year, so that
No. of civil days from A to B = 354Y
No. of civil days from S to Ś = 365 ¼ Y
Therefore, no. of civil days from B to Ś
= civil days from A to Ś – civil days from A to B
= civil days from A to B
= civil days from A to S + civil days from S to Ś – civil days from A to B
= Sankrānti tithi + 365 ¼ Y - 354Y = Sankrānti tithi + 11 ¼ Y
= Sankrānti tithi + 10Y + 11/8 Y = X, say,
Where Sankrānti tithi denotes the number of tithis from A to S.
In round numbers, these will be equal to the number of civil days from A to S.
The number of intercalary months corresponding to X civil days (constituting the difference in civil days between Y solar years and Y lunar years) will be obtained by

dividing (1-1/60)X by 30; the remainder of this division will give the residue of the intercalary months, i.e., the number of civil days falling from C to Ś.

This rule is true for 100 years, because

100 solar yeas = 36525 civil days

100 lunar years = 35400 civil days

Difference = 1125

Less difference/60 = -19

1106

This divided by 30 gives 36 months and 26 days. This is also equal to the intercalary months and days corresponding to 100 solar years.

For, no. of intercalary months in 100 solar years

= months = 36 months 26 days

Let R be the remainder obtained on dividing (1-1/60)X by 30. Then

No. of civil days from B to C = X – R.

Let the number of tithis from C to T be denoted by C_t and the seasons (1 solar year = 6 seasons) falling therein be denoted by s. Then

No. of civil days from C to T = C_t - s.

This is true, because

1 solar year = 365 civil days = 371 tithis - 6 seasons,

So that, no. of civil days = no. of tithis – no. of seasons.

Thus, no. of civil days from B to T = X – R + C_t – s.

This will give the Ahargaṇa, i.e. the number of civil days elapsed since the Chaitrādi or Dhruvābdādi.

Substracting 357Y from it, we get

Dyugaṇa = X – R + C_t – s – 357Y = X – R + C_t – s - 3Y (mod 7)

Thus, Dyugaṇa = Ahargaṇa - 357Y.

Since 357 is a multiple of 7, the remainder obtained by dividing the Dyugaṇa by 7 will be the same as that obtained by dividing the Ahargaṇa by 7.

The Ahargaṇa, and likewise the Dyugaṇa, thus obtained may differ by 1 from its actual value. To check this, it is divided by 7. If the remainder of this division when counted from the day for which the epochal constants are stated yields the current day, it is to be understood that the Ahargaṇa or Dyugaṇa is correct. If that yields the previous day, the Ahargaṇa or Dyugaṇa should be increased by 1; if that yields the next day, it should be diminished by 1.

Rationale by N.K. Majumdar-

(1) In 1 lunar year of 354 days, there are 12 x 30 = 360 tithis. In 1 solar years of 365 ¼ days, there are (365 ¼ -354) = 11 ¼ or (10 + 10/8) additional tithis. This is multiplied by the number of years elapsed to get the total number of such additional tithis (i.e. omitting complete lunar years) from Varṣādi of Epoch to Varṣādi of current year. The number of Samkrānti Tithis at Varṣādi of Epoch added to the total number of tithis calculated above gives the total number of additional tithis from Chaitrādi of Epoch to Varṣādi of current year. The total number thus found is reduced to Sāvana days by deducting its 60th part from itself: this is based on the assumption that 354 days are equal to 360 tithis. If the number of Sāvana days thus obtained is divided by 30, the quotient (which is not used in the calculations) gives the number of adhimāsas (intercalary months) for the years elapsed from the Epoch, and the

remainder gives the Adhiśeṣa or lunar tithis from Chaitrādi to Varṣādi of current year.
(2) Deducting the number of Adhiśeṣas from the additional lunar tithis found before, the number of additional days (i.e. omitting 354 days for each year) from Chaitrādi of Epoch to Chaitrādi (instead of Varṣādi) of current year is obtained. From this number of additional days are deducted 3 days for each year, to make the group of omitted days per year equal to 357, a multiple of 7.
(3)The number of tithis elapsed from the Chaitrādi of the current year is added, and this is converted to sāvana days by deducting the number of seasons, i.e. by deducting 1 day for every 2 months or 60 tithis. The result is named Dyugaṇa to distinguish it from Ahargaṇa. Ahargaṇa is thus equal to Dyugaṇaplus 357 days multiplied by the number of years elapsed from the Epoch.
The word “dhruvavāsara” in the Sanskrit text means “the day for which the epochal constants are computed” i.e. Saturday. According to Sūryadeva Yajvā, it means “the day which occurs next to the day for which the epochal constants are computed” i.e. Sunday. It means that, the epochal day of Laghumānasa is Sunday, not saturday
रविमध्यमानयनम्
द्युगणोऽधो दशघ्नाब्दयुतः खागा (७०) प्तवर्जितः। अष्टघ्नाब्दोनितोऽर्कां(१२) शाः प्रक्षेप्योब्दाष्टमः कलाः॥५॥
Mean Sun
Set down the Dyugaṇa in two places (one below the other). In the lower place add 10 times the years elapsed (since the epoch, and divide by 70. Deduct the quotient from the Dyugaṇa put down at the other place; further substract 8 times the years elapsed. Whatever is thus obtained is in degrees. To this add minutes equal to 1/8 of the number of years elapsed. (Thus is obtained the mean motion of the Sun since the epoch.)
Thus, Sun’s mean motion since the epoch = degrees + (Y/8) mins.
Where D = Dyugaṇa, Y = years elapsed since epoch.
Rationale-According to Āryabhaṭa-1,
Sun’s mean daily motion = degrees = degrees
= (1- 1/70) degrees – 2/5 secs. approx. (Śiṣyadhīvṛddhida tantra, 1/33)
Mañjula neglects 2/5 secs. and takes Sun’s mean daily motion = (1- 1/70) degrees approx. (1)
Also according to Āryabhaṭa-1,
Sun’s mean motion for 357 days = (352 – 1/7) degrees + (1/5) mins.
= - 8 degrees + (1/5) mins.
Mañjula takes (1/8) mins. in place of (1/5) mins, so that according to him
Sun’s mean motion for 357 days = - 8 degrees + (1/8) mins. (2)
Let A = Ahargaṇa, D= Dyugaṇa, Y = number of years elapsed since the epoch. Then
So that, using (1) and (2), we have, according to Mañjula,
Sun’s mean motion corresponding to Ahargaṇa A,
= (1- 1/70) D degrees - 8 Y degrees + (1/8) Y mins.
= degrees + (1/8) Y mins.
This is increased by the Sun’s position at the epoch gives the Sun’s mean longitude.
Note-If 8Y > D- , then, according to one manuscript, we should substract 8Y from 180 + D – (D + 10Y)/70. This is obviously true.

चन्द्रमध्यमानयनम्
विश्व (१३) घ्नो द्युगणो द्विष्ठस्त्रिघ्नाब्दद्युगणोनितः। अष्टाङ्गा (६८)प्त जिन(२४)घ्नाब्दयुतो भागादिकः शशी॥६॥

Mean Moon

Set down 13 times the Dyugaṇas in two places. In one place diminish it by 3 times the years elapsed and also by the Dyugaṇa; divide that by 68. Add what is thus obtained as well as 24 times the years elapsed to the quantity put down at the other place. (Then is obtained mean motion of) the Moon (since the epoch), in terms of degrees.

Thus, Moon's mean motion since epoch = 13D + + 24Y degrees,
Where D = Dyugaṇa, Y = number of years elapsed since the epoch.
Rationale- According to Āryabhaṭa-1,
Moon's mean daily motion = degrees = degrees – (1/150) secs.
Mañjula neglects (1/150) secs. and takes
Moon's mean daily motion = degrees (1)
Again according to Āryabhaṭa-1,
Moon's mean daily motion for 357 days =   revs.
= 13 revs. + (24 – 3/72) degrees
= (24 – 3/72) degrees, neglecting revolutions.
Mañjula replaces (3/72) by 3/68), and takes
Moon's mean daily motion for 357 days = (24 – 3/68) degrees, neglecting revolutions. (2)
Using (1) and (2), Mañjula takes
Moon's mean motion since the epoch = 13D + + 24Y degrees.
This increased by the Moon's position at the epoch gives the Moon's mean longitude.

चन्द्रोच्चमध्यमानयनम्
द्युगणो द्वि(२) गुणाब्दोनश्चन्द्रोच्चांशा नवोद्धृताः। खवेद(४०)घ्नाब्दसंयुक्तास्साष्टं(८) शाब्दकलोनिताः॥७॥

Moon's Apogee

Substract 2 times the years elapsed from the Dyugaṇa and divide that by 9. To this, add 40 times the years elapsed. These are the degrees of the Moon's apogee. Sustract minutes equal to (1 + 1/8) times the years elapsed. (Then is obtained the mean motion of the Moon's apogee since the epoch).

Thus, mean motion of Moon's apogee since the epoch
= degrees – (1+ 1/8) mins.
Where D = Dyugaṇa, Y = number of years elapsed since the epoch.
Rationale- According to Āryabhaṭa-1,
Mean daily motion of Moon's apogee = degrees
= 1/9 degrees + 1/61 min.
Mañjula neglects 1/61 min and takes
Mean daily motion of Moon's apogee = 1/9 degrees (1)
Again, according to Āryabhaṭa-1,
Mean motion of Moon's apogee for 357 days
= degrees = (40-2/9) degrees – 6/8 min.

= (40- 2/9) degrees – 9/8 min + 3/8 min.
Mañjula neglects 3/8 min and takes
Mean motion of Moon’s apogee for 357 days = (40- 2/9) degrees – 9/8 min. (2)
Using (1) and (2), Mañjula gives
Mean motion of Moon’s apogee since the epoch
= D/9 degrees + (40- 2/9) Y degrees – 9/8 Y mins.
= degrees – (1+ 1/8) Y mins.
This increased by the position of the Moon’s apogee at the epoch gives the mean longitude of the Moon’s apogee.

In the case of mars, Śīghroccha of Mercury, Śīghroccha of Venus, Saturn, and Moon’s ascending node, whose mean longitudes have been stated for the completion of the Sun’s revolution in Śaka 854, Mañjula takes the completion of the Sun’s revolution in Śaka 854 as the epoch and proceeds as follows: He first finds the Sun’s mean motion since epoch, then obtains the corresponding mean motion of the planet, and then adds to it the epochal mean position of the planet. The Sun’s mean motion sincethe epoch is called Dhruvādyarka and is obtained by adding the number of years elapsed since the epoch, treated as revolutions, to the Sun’s mean longitude in terms of signs etc.

भौममध्यमानयनम्-ध्रुवाद्यर्कात् कुजो-द्वाभ्यां (२) नृपात् (१६) घ्नाच्चेषुखेषुभिः (५०५)।

Mean Mars

The Dhruvādyarka (i.e. the Sun’s mean longitude in terms of signs etc. with the years elapsed since the epoch written before it in place of revolutions) divided by 2, plus 16 times the Dhruvādyarka divided by 505, gives the mean motion of Mars since the epoch.

Thus, Mean motion of Mars since the epoch = S/2 + 16S/505,
Where S = Dhruvādyarka.
Rationale- According to Āryabhaṭa-1,

=

= (1/2) + (16/505) approx.
The mean motion of Mars since the epoch, increased by its epochal position, gives its mean longitude.

बुधशीघ्रोच्चानयनम्-सप्त(७)घ्नादृतुवेदै(४६)घ्नाश्चतुर्(४)घ्न रविणा युतः॥८॥

Mean Śīghroccha of Mercury

The Dhruvādyarka multiplied by 7 and divided by 46, when added to 4 times the Sun’s mean longitude (in terms of signs etc.) gives the mean motion of the Śīghroccha of Mercury since epoch.

Thus, Mean motion of Śīghroccha of Mercury since epoch = 4S + 7S/46,
Where S = Dhruvādyarka.
Rationale- According to Āryabhaṭa-1,

= = 4 + (7/46) approx.

गुरुमध्यमानयनम्-रूप(१)घ्नाद्भास्करैर्जीवो भू(१)घ्नाच्च रदखेन्दुभिः(१०३२)।

Mean Jupiter

The Dhruvādyarka multiplied by 1 and divided by 12, plus the Dhruvādyarka multiplied by 1 and divided by 1032, gives the mean position of Jupiter since the

epoch.
I.e. Mean motion of Jupiter since the epoch = S/12 + S/1032
Where S = Dhruvādyarka
Rationale- According to Āryabhaṭa-1,

= = 1/12 + 1/1023 approx.

Mañjula takes 1/1032 in place of 1/1023. Hence the rule.
The mean motion of Jupiter since the epoch, increased by its epochal position, gives the mean longitude of Jupiter.
शुक्रशीघ्रोच्चानयनम्-दिग्(१०)घ्नात् षड्(६)भिस्सितो दिग्(१०)घ्नात् त्रिजिनां(२४३)शेन वर्जितः॥९॥
Mean Śīghroccha of Venus
The Dhruvādyarka multiplied by 10 and divided by 6, minus the Dhruvādyarka multiplied by 10 and divided by 243, gives the mean position of Śīghroccha of Venus since the epoch.
I.e. mean motion of Śīghroccha of Venus since the epoch = 10S-10S/243,
Where S = Dhruvādyarka
Rationale- According to Sūrya-siddhānta-

= = 10/6 + 10/243 approx.

The mean motion of Śīghroccha of Venus since the epoch, increased by its epochal position, gives the mean longitude of Śīghroccha of Venus.
शनिमध्यमानयनम्-षड्गुणादयुते (१००००)नार्किश्चन्द्र(१)घ्नाच्च खवह्निभिः।
Mean Saturn
The Dhruvādyarka multiplied by 1 and divided by 30, plus the Dhruvādyarka multiplied by 6 and divided by 10000, gives the mean position of Saturn since the epoch.
I.e. Mean motion of Saturn since the epoch = S/12 + S/1032
Where S = Dhruvādyarka
Rationale- According to Brahmagupta,

= = 1/30 + 6/10096 approx.

Mañjula takes 1/10000 in place of 1/10096. Hence the rule.
The mean motion of Saturn since the epoch, increased by its epochal position, gives the mean longitude of Saturn.
चन्द्रपातानयनम्-नखैः (२०) पञ्चाङ्गनेत्रै(२६५)श्च चन्द्रास्तो विलोमगः॥१०॥
Moon’s Ascending Node
Divide the Dhruvādyarka in one place by 20 and in another place by 265 (and add the two quotients): this gives the motion, since the epoch, of the Moon’s ascending node, which moves in the contrary (or negative) direction.
I.e. Motion of Moon’s ascending node since the epoch = S/20 + S/265,
Where S = Dhruvādyarka.
Rationale- According to Āryabhaṭa-1,

= = 1/20 + 1/266 approx.

Mañjula takes 1/265 in place of 1/266. Hence the rule.
The motion of Moon’s ascending node since the epoch, substracted from its position

at the epoch, gives the mean longitude of the Moon’s ascending node.
The rules in verses 8-10 are exactly the same as found in some manuscripts of Lalla’s Śiṣya-dhī-vṛddhida tantra-
रविर्द्वि(२) भक्तो रविराहतो नृपैः(१६) शराभ्रबाणै (५०५) र्हृतयुक्कुजोऽथवा।
रविर्नग (७) घ्नोऽङ्गयुगो (४६)द्धृतश्चतु(४)र्गुणार्कयुक्तो भवतीन्दुजो ध्रुवः॥
रविर्विभक्तो रवि(१२)भिर्हृतो रवि रदाभ्रचन्द्रै(१०३२)स्त्रिदशाधिपो भवेत्।
रविर्दश(१०)घ्नादृतिभिर्हृतात् सितः पुनस्ततो रामजिनां(२४३) शवर्जितः॥
रवी रस(६)घ्नोऽयुत(१००००) भाजितो भवेद्धृतो रविः खाग्नि (३०)भिरर्कजोऽथवा।
नखो(२०)द्धृतो भास्कर इष्वृतुद्वि(२६५)भिर्विभाजितश्चन्द्ररिपुर्विलोमगः॥
In commentaries on Śiṣya-dhī-vṛddhida, Mallikārjuna Sūri and Bhāskara-2 have not commented on these verses, but Sūryadeva Yajvā, in his commentary on Laghumānasa has ascribed them to Lalla.
Yallaya has shown that the rules stated above to compute the mean longitudes of the planets will yield fairly good results for 100 years from the epoch. In the case of Sun, Moon, Moon’s apogee and ascending node, Mars, Śīghroccha of Mercury, and Jupiter, the mean longitude obtained from them will agree with that obtained by using the constants and Bīja of the Āryabhaṭa school. In the case of Śīghroccha of Venus, it will agree with that obtained by using the constants of the Sūrya-siddhānta, and in the case of Saturn, with that obtained by using the constants of the Brāhma-Sphuṭa-Siddhānta. The difference, if any, will be small and negligible. Sūryadeva Yajvā has same view.
इति लघुमानसे मध्यमगत्यधिकारो द्वितीयः।
Thus ends chapter 2 about mean motion in Laghumānasa.
अथ स्फुटाधिकारः तृतीयः (Chapter 3-True Motion)
केन्द्रोत्पन्नभुजकोट्योः धनर्णप्रतिपादनम्
ग्रहस्स्वोच्चोनितः केन्द्रं तदूर्ध्वाध्वाधोर्धजो भुजः। धनर्णं पदशः कोटिर्धनर्णधनात्मिका॥११॥
Kendra and signs of Bhuja and Koṭi
The longitude of a planet diminished by the longitude of its uccha, (Mandoccha or Śīghroccha), is its Kendra. The bhuja thereof is positive or negative according as the Kendra is greater or less than six signs; whereas the koṭi (i.e. the complement of the bhuja) is positive, negative, negative, and positive in the four quadrants (of the Kendra), (respectively).
That is,
Manda-kendra = Planet – Mandoccha
Śīghra-kendra = Planet – Śīghroccha
The bhuja corresponding to the Kendra is defined as follows: When the Kendra is less than 3 signs, the Kendra itself is the bhuja; when the Kendra is greater than 3 signs and less than 6 signs, bhuja = 6 signs –kendra; when the Kendra is greater than 6 signs and less than 9 signs, bhuja = Kendra – 6 signs; and when the Kendra is greater than 9 signs but less than 12 signs, bhuja = 12 signs – Kendra. That is, the bhuja is the arcual distance of the planet from its Uccha or Nīcha, whichever is nearer.
The bhuja is negative, negative, positive, and positive, and koṭi is positive, negative, negative, and positive, according as the Kendra is 0 to 3 signs, 3 signs to 6 signs, 6 signs to 9 signs, and 9 signs to 12 signs. The rule is based on the fact that the

bhujaphala is negative, negative, positive, and positive and koṭiphala is positive, negative, negative, and positive in the first, second, third, and fourth quadrants, respectively.

भुजकोटि-तत्काष्ठयोर्ज्यानयनम्
ओजे पदे गतैष्याभ्यां बाहुकोटी समेऽन्यथा। चतुस्त्र्यैकघ्नराश्यैकं दोःकोट्योरंशकाः कलाः॥१२॥
Bhuja and Koṭi-In the odd quadrant, the traversed and untraversed arcs (of the Kendra) are defined as Bāhu (or Bhuja) and Koṭi (respectively); in the even quadrant, it is just the reverse.
To find the value of the Rsine of Bhuja or Koṭi, multiply the first sign by 4, the second sign by 3, and the third sign by 1, and add. Take the same as degrees and an equal number as) minutes.
The second half of the text gives the following table of Rsine differences for R = $8^0 8'$.

Arc	Rsine	Rsine-difference
0	0	$4^0 4'$
30^0	$4^0 4'$	$3^0 3'$
60^0	$7^0 7'$	$1^0 1'$
90^0	$8^0 8'$	--

Example-Using this table, $8^0 8'$ sin 80^0 may be calculated as follows-
$8^0 8'$ sin 80^0 = $8^0 8'$ sin (30^0 + 30^0 + 20^0) = $8^0 8'$ sin (1st sign + 2nd sign + 2/3. 3rd sign)
= $(4 + 3 + 2/3)^0 + (4 + 3 + 2/3)' = 7^0 40' + 7'40'' = 7^0 47' 40''$
Simplified method for calculating Rsine-Sūryadeva and Parameśvara have given a simplified method for calculating the value of $8^0 8'$ sin θ according to Mañjula.
(1) To calculate $8^0 8'$ sin θ, when θ <1 sign.
Let $\theta = \alpha^0\ \beta'\ \gamma''$, Then
$8^0 8' \sin (\alpha^0\ \beta'\ \gamma'') = 8\ (\alpha^0\ \beta'\ \gamma'') + 8\ (\alpha'\ \beta''\ \gamma''')$
(2) To calculate $8^0 8'$ sin θ, when 1 sign < θ < 1 signs.
Let θ = 1 sign $\alpha^0\ \beta'\ \gamma''$, Then
$8^0 8' \sin (1^s\ \alpha^0\ \beta'\ \gamma'') = 4^0 4' + 6\ (\alpha'\ \beta''\ \gamma''') + 6\ (\alpha''\ \beta'''\ \gamma'''')$
(3) To calculate $8^0 8'$ sin θ, when 2 signs < θ < 3 signs.
Let θ = 2 signs $\alpha^0\ \beta'\ \gamma''$, Then
$8^0 8' \sin (2^s\ \alpha^0\ \beta'\ \gamma'') = 7^0 7' + 2(\alpha'\ \beta''\ \gamma''') + 2\ (\alpha''\ \beta'''\ \gamma'''')$
Illustrative examples-
(1) Calculate $8^0 8'$ sin (4^0 10' 15")
$8^0 8'$ sin (4^0 10' 15") = 32' 80" 120"' + 32" 80"' 120"" = 33' 55" 22"'
Modern value = 35' 29" 33"'
(2) Calculate $8^0 8'$ sin (1 sign 15^0 40')
$8^0 8'$ sin (1 sign 15^0 40') = 4^0 90' 240" + 4' 90" 240"' = 5^0 39' 34"
Modern value = 5^0 49' 4"
(3) Calculate $8^0 8'$ sin (2 signs 10^0 40')
$8^0 8'$ sin (2 signs 10^0 40') = 7^0 20' 80" + 7' 20" 80"' = 7^0 28' 41" 20"'
Modern value = 7^0 40' 32"
Mallikārjuna Sūri's true multipliers-
The use of Mañjula's table of Rsine-differences will not yield good result when the bhuja is not exactly equal to 1 sign, 2 signs or 3 signs. To get rid of this, Mallikārjuna

Sūri has prescribed a rule to obtain true multipliers to be used for interpolating the values within the three signs of the bhuja. This is based on the following table giving the preceding and succeeding multipliers for the three signs.

	succeeding multiplier	preceding multiplier	half of their sum	half of their diff.
3rd sign	1	3	2	1
2nd sign	3	4	3 ½	½
1st sign	4	4 ½	4 ¼	¼
Beginning of 1st sign	4 ½			

Assuming the degrees and minutes of the bhuja to be equal to and denoting half the sum of the preceding and succeeding multipliers by s and half the difference of those multipliers by D, the formula for the true multiplier given by Mallikārjuna Sūri is-

True multiplier = S -

True multiplier for 1st sign = $4^0$15' - = $4^0$15' -

True multiplier for 2nd sign = $3^0$30' - α' β"

True multiplier for 3rd sign = 2^0 - 2 α' β"

Mallikārjuna Sūri's true multipliers have been actually used in some manuscripts to obtain Rsines. 2 examples are given-

Example 1- Find $8^0$8' sin (1^s 29^0 53' 21")

Here true multiplier = $3^0$30' – 29' = $3^0$1'

Now = = 3^0 0' 17" 46'"

Therefore $8^0$8' sin (1^s 29^0 53' 21") = 7^0 0' 17" 46'" + 7' 0" 17'" = 7^0 7' 18" 3'"

(Modern value = 7^0 2' 8" 51'" and Mañjula's value = 7^0 6' 19" 26'")

Example 1- Find $8^0$8' sin (1^s 5^0 28' 5")

Here true multiplier = $3^0$30' – 5' = $3^0$25'

Now = = 37' 21" 20'"

Therefore $8^0$8' sin (1^s 5^0 28' 5") = 4^0 37' 21" 2'" + 4' 37" 21'" = 4^0 41' 58" 41'"

(Modern value = 4^0 43' 9" 41'" and Mañjula's value = 4^0 37' 21" 18'" 30"")

Bhūdhara's Table-This gives Rsines for R = $8^0$8' at intervals of 1^0-

Table of Rsines (R = $8^0$8')

Degrees	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Rsines (deg.)	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2
(secs.)	8 ½	17	25	34	42	51	59	8	16	25	33	41	49	57	6 ¼
Degrees	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Rsines (deg.)	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4
(secs.)	14	22	31	39	47	55	3	11	18	26	34	41	49	57	4
Degrees	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Rsines (deg.)	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
(secs.)	11	18	25	33	40	47	54	1	7	14	20	26	33	39	45
Degrees	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Rsines (deg.)	5	5	6	6	6	6	6	6	6	6	6	6	6	6	7
(secs.)	51	57	3	8	14	19	24½	30	35	40	45	49	54	58	2½
Degrees	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75

Rsines (deg.)	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
(secs.)	7	11	15	18	22	26	29	33	36	39	42	44	47	49	51
Degrees	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Rsines (deg.)	7	7	7	7	8	8	8	8	8	8	8	8	8	8	8
(secs.)	53	55	57	59	1	2	3	4	5	6	6	7	7	8	8

सूर्यादिग्रहाणां मन्दच्छेदाः

सूर्यात् जिनाश्विनो (२२४)ऽगाङ्का(९७) श्शरवेदाः (४५) खखेन्दवः(१००)।
द्व्यङ्काः(९२) खदन्ता(३२०) स्त्रिरसा (६३) श्छेदाः कोट्यर्धसंस्कृताः॥१३॥

Manda-Chheda or Manda Divisors - The "(manda) divisors" (chheda) for the Sun etc. (i.e. Sun, Moon, mars, Mercury, Jupiter, Venus, and Saturn) are 224, 97, 45, 100, 92, 320, and 63, each corrected by half the (manda) koṭijyā.

The constants 224 etc. stated above are the values of 60 x 488/r, where r is the value in minutes of the greatest equation of the center. These constants are to be treated as degrees.

The following table gives the values of the greatest equation of the centre corresponding to the above constants:

Planet	Manda divisor (= 488 x 60/r)	Greatest equation of the centre (= r)
Sun	224	130' 43"
Moon	97	301' 50"
Mars	45	650' 40"
Mercury	100	292' 48"
Jupiter	92	318' 29"
Venus	320	91' 30"
Saturn	63	464' 46"

Sūryadeva Yajvā derives the above value of manda divisors (manda chhedas) by taking 130'48", 302', 651', 293', 318', 91' 30", and 470' as the greatest equations of the centres for the Sun, Moon, Mars, Mercury, Jupiter, Venus, and Saturn respectively.

The constants 224, 97, etc. stated in the text are sometimes called (madhyama) manda-vyāsa, (madhyama) manda-chheda, or (madhyama) manda-hāra, and after being corrected by half the corresponding manda-koṭijyā (Rsine of bhuja) they are called sphuṭa manda-vyāsa, sphuṭa manda-chheda, or sphuṭa manda-hāra.

The tem "koṭi" in the text is used in the same sense of "koṭijyā". In this book, the terms bhuja and koṭi have been generally used in the sense of bhujajyā and koṭijyā.

भुजो लिप्तिकृतश्छेदभक्तो ग्रहफलांशकाः।
ग्रहाणां मन्दस्फुटगत्यानयनम्-कोटिर्गतिघ्नी छेदाप्ता व्यस्तं गतिकलाफलम् ॥१४॥

Mandaphala and Manda-gatiphala

The bhujajyā (of a planet), reduced to minutes and divided by the (manda) divisor, gives the degrees of the planet's (manda) phala (i.e. equation of the centre). The koṭijyā (of a planet), multiplied by the mean daily motion of the planet (in minutes)

and divided by the (manda) divisor (for that planet) gives the minutes of the (manda) gatiphala which is to be applied (to the mean daily motion of the planet) contrarily to the sign of the koṭijyā: (the result is the true or true-mean motion of the planet).
In case of Moon, motion of its apogee amounts to 6'41" per day, which is not negligible, so Yallaya suugests that in place of "the mean daily motion of the Moon" one should use "the mean daily motion of Moon's Kendra (for anomaly" to find the Moon's gatiphala.
Let θ be the planet's manda-kendra reduced to bhuja and r the radius of the planet's manda epicycle (or, what is the same thing, the planet's greater equation of the centre). Then
Planet's mandaphala = R = radius.
Taking the hypotenuse (mandakarṇa) of the planet to be equal to
R + (Rcos θ) x r/2R
And assuming that the manda epicycle corresponds to this distance,
= = mins. = degrees,
Because 60 x 60/R = 60 x 60/3438 = 1 approx.
= degrees
Also, planet's manda gatiphala = = . degrees
= . minutes = . minutes
= minutes = minutes approx,
Neglecting the motion of the planet's apogee.
Sūryadeva Yajvā's rationale for planet's manda-gatiphala:
True (or true-mean) daily motion = R X ,
where H = planet's hypotenuse or distance.
= . (mean daily motion)
= mean daily motion - -
= mean daily motion - -
= mean daily motion - -
Therefore, manda gatiphala = - mmins.
Example-let the Sun's Kendra be $6^s\ 1^0 30'$. Then
Bhuja = $1^0 30'$, koṭi = $2^s\ 28^0\ 30'$
Bhujajyā = $8(1^0 30') + 8(1" 30''')$ Koṭijyā = $-(4^0\ 4' + 3^0 3') + 56'\ 60" + 56"\ 60'''$
= 12'12" = 12' approx = $-(7^0 7' + 57'57") = -8^0 4'57" = -8^0$ approx.
Therefore, Sun's mandaphala = = degrees
= degrees = 3' approx.
Sun's true Kendra = 6s 10 30' + 3' = 6s 10 33'
Sun's gatiphala = = = = 2' 9"
Therefore, Sun's true daily motion = 59' 8" + 2' 9" = 61' 17" = 61' approx.
Mallikārjuna Sūri's interpretation-Mañjula has applied hypotenuse proportion in finding planet's mandaphala which has not been generally used by Hindu astronomers. Without the hypotenuse proportion, Mañjula's formula will be of the form:
Planet's mandaphala = degrees,
Where θ is the planet's mean anomaly and r the radius of planet's manda epicycle.
If this formula is used, we will have

Sun’s mandaphala = degrees,
θ being the Sun’s mean anomaly reduced to bhuja; and
Moon’s mandaphala = degrees,
θ being the Moon’s mean anomaly reduced to bhuja.
The formula for the planet’s manda-gatiphala will consequently take the form
Planet’s manda-gatiphala = mins.,
Where θ is the planet’s mean anomaly reduced to bhuja and r the radius of the planet’s manda epicycle.
Mallikārjuna Sūri was the first to raise objection to use of hypotenuse proportion by Mañjula. He explained Mañjula’s rule as per general methods of Hindu astronomy-
छेदा जिनाश्विनोऽगाङ्का रवीन्द्वोः स्फुटकर्मणि । गतिस्फुटार्थमर्केन्द्वोश्छेदौ तावेव मानसे॥
कोट्यर्धसंस्कृतौ छेदौ रवीन्द्वोर्बिम्बसाधने।
I.e., “The divisors 224 and 97 (themselves)” are to be used for finding the true positions of the Sun and Moon (respectively). The same divisors have been prescribed in the (Laghu-)mānasa for finding the true daily motion of the Sun and Moon (also). These divisors s corrected by half the (manda) koṭijyā are meant to be usedin the case of finding the diameters of the Sun and Moon.”
Thus, according to Mallikārjuna Sūri, one should use the following formulae in the case of the Sun:
Sun’s mandaphala = degrees
Sun’s mandagatiphala = mins.
θ being the Sun’s mean anomaly reduced to bhuja; and the following formulae in the case of the Moon:
Moon’s mandaphala = degrees
Moon’s mandagatiphala = mins.
θ ’ being the Moon’s mean anomaly reduced to bhuja.
Yallaya has mentioned view of Mallikārjuna Sūri as follows-
मल्लिकार्जुन सूरिणा रविचन्द्रयोः फलानयने (गतिफलानयने) च कोट्यर्धसंस्कृतौ छेदौ न भवतः बिम्बसाधने कोट्यर्धसम्स्कृतौ छेदौ स्यातामित्युक्तम्। तथाऽस्य सार्धश्लोकौ लिख्यन्ते-
छेद जिनाश्विनोऽगाङ्का रवीन्द्वोः स्फुटकर्मणि। गतिस्फुटार्थमर्केन्वोश्छेदौ तावेव मानसे॥
कोट्यर्धसंस्कृतौ छेदौ रवीन्द्वोर्बिम्बसाधने।
i.e. Mallikārjuna Sūri has said that in finding the mandaphala and mandagatiphala of the Sun and Moon, the divisors should not be corrected by half the (manda) koṭijyā, but in finding the diameters of the discs of the Sun and Moon, the divisors are to be corrected by half the (manda) koṭijyā. Below are given 1½ verses written by him: “The divisors 224 and 97 (themselves” are to be used for finding the true positions of the Sun and Moon (respectively) the same divisors have been prescribed in the (Laghu-) mānasa for finding the true daily motion of the Sun and Moon (also). These divisors are corrected by half the (manda) koṭijyā are meant to be used in the case of finding the diameters of the disc of the Sun and Moon.
Following this, Bhūdhara says-
कोट्यर्धसंस्कृतौ छेदौ रवीन्द्वोर्बिम्बसाधने। गतिस्फुटर्थमर्केन्द्वोश्छेदौ तावेव मानसे॥
इति परिभाषया अत्र न कोट्यर्धसंस्कारः।
i.e. “The divisors as corrected by half the (manda) koṭijyā should be used in the case of finding the diameters of the discs of the Sun and Moon. But in case of finding the

true positions and true daily motions of the Sun and Moon, the same divisors (uncorrected by half the manda) are to be used. According to this instruction, one has not to apply here the correction of half the (manda) koṭijyā."

Bhūdhara has actually followed Mallikārjuna Sūri's instruction and while illustrating Mañjula's rules for finding the trye position and the true daily motion of the Moon, he has used the divisor 97 without correcting it by half the manda koṭijyā.

ग्रहाणां शीघ्रच्छदानयनम्-कुजजीवशनिच्छेदा युगाग्न्यग(४,३,७)हता हृताः।
तिथिशैलर्तु (१५,७,६)भिर्व्यासा मूर्च्छनेशा (२१,११) ज्ञशुक्रयोः॥१५॥
ते दोस्त्र्यंशयुताश्शीघ्रच्छेदास्स्युः कोटिसंस्कृताः।
ग्रहशीघ्रोच्चनिर्णयः-ताराग्रहार्कयोश्शीघ्रश्शीघ्रोच्चमितरो ग्रहः॥१६॥

Śīghra-vyāsa and Śīghra divisors-The manda divisors of Mars, Jupiter, and Saturn, multiplied by 4, 3, and 7 (respectively) and divided by 15, 7, and 6 respectively, are the (Śīghra) vyāsas (for Mars, Jupiter, and Saturn respectively); 21 and 11 are those for Mercury and Venus respectively. These increased by one-third of the bhujajyā and corrected by the koṭijyā are the Śīghra divisors. Out of a star planet and the Sun, the faster one is the Śīghroccha and the other (slower one) the planet.

That is, Śīghra divisor = Śīghra-vyāsa + Śīghra- bhujajyā Śīghra- koṭijyā,

where the Śīghra-vyāsa of the planets are given by the following table:

Śīghra-vyāsa of the planets

Planet	Śīghra-vyāsa (or Madhyama Śīghra-vyāsa)
Mars	(45 + mandakoṭijyā /2) X 4/15
Mercury	100 X 7/33 or 21
Jupiter	(92 + mandakoṭijyā /2) X 3/7
Venus	320 X 1/29 or 11
Saturn	(63 + mandakoṭijyā /2) X 7/6

In the case of Mercury and Venus, the second term involving mandakoṭijyā being insignificant has been dropped by Mañjula.

Let θ' be the planet's Śīghra-kendrs reduced to bhuja and r' minutes the radius of the planet's Śīghra epicycle. Then

Planet's Śīghraphala = , (1)

taking the Śīghra-karṇa to be equal to R Śīghrakoṭiphala

= = mins. = degrees,

Because 60 X 60/R = 1 approx.

Mañjula, replaces the first term in the denominator, viz. 60 X 488/r', by

or Śīghra-vyāsa + ,

and so he takes Śīghraphala = = , (2)

where Śīghra divisor = Śīghra-vyāsa + 80 8' sin θ/3 .

Formula (2) was probably supposed to yield better result, agreeing with observation, than formula (1). When mandakendra is equal to 90^0, the Śīghra-vyāsa of the planets take the following values:

Planet	Śīghra-vyāsa
Mars	12^0
Mercury	21^0
Jupiter	39^0 26'

Venus	11^0
Saturn	73^0

The Śīghra-vyāsa as defined above, is then equal to

+ ,

Where r’ is the radius of the śīghra epicycle, or roughly, the greatest śīghra correction.

If, in place of r’, one uses the value of the greatest śīghra correction, as given in the Makaranda-sāraṇī, and śīghra-bhuja be taken equal to 90^0, then the Śīghra-vyāsas obtained will be as shown in the following table:

Planet	r’	Śīghra-vyāsa (= 488 X 60/r’)
Mars	1968’	12^0
Mercury	1207’	21^0 33’
Jupiter	676’	40^0 35’
Venus	2132’	10^0 57’ or 110
Saturn	380’	74^0 20’

Praśastidhara and Sūryadeva Yajvā use the term sphuṭa-(śīghra)vyāsa (true śīghravyāsa) in the sense of śīghravyāsa +

Using this term, śīghra divisor = sphuṭa śīghravyāsa + 808’ cosθ’

According to N. K. Majumdar, the manda divisor in verse 5 stands for the manda divisor (as defined in verse 3) before it is corrected by half the manda koṭijyā. But this is against the interpretation of the commentators. According to them, the manda divisor in verse 5 is the same as defined in verse 3.

Further since in finding the śīghra divisor, Mañjula makes the correction of śīghra koṭijyā and not of half of śīghra koṭijyā, N. K. Majumdar thinks that the correction of half the manda koṭijyā in finding the manda divisor may be an error. This si unacceptable as the manda and śīghra operations stand on different principles. Moreover, no commentator has expressed such a doubt.

The second half of verse 6 gives the definition of the śīghroccha of a planet is the Sun if the Sun is faster than the planet, or the planet itself if the planet is faster than the Sun.

Śīghroccha of the planets

Planet	Śīghroccha
Mars	Sun
Mercury	Mercury itself
Jupiter	Sun
Venus	Venus itself
Saturn	Sun

This shows that the Śīghroccha of a superior planet (Mars, Jupiter, or Saturn) is the Sun and that of an inferior planet (Mercury or Venus) is the planet itself.

ग्रहाणां मन्दस्फुटगतीनां शीघ्रस्फुटीकरणम्-

व्यासं शीघ्रफलार्कां(१२)शभागोनं ग्रहशीघ्रयोः। गत्यन्तरघ्नं छेदाप्तं त्यक्त्वा शीघ्रगतेर्गतिः॥१७॥

True daily motion of a Planet

Substract one-twelfth of the Śīghraphala from the (Śīghra) vyāsa; then multiply that by the difference between te (true-mean) daily motion of the planet and the daily motion of its Śīghroccha; then divide that by the śīghra divisor; and then substract that from the daily motion of the śīghroccha, the result is the true daily motion (of that planet).

That is, true daily motion = Śīghroccha-gati –

Where śīghrakendragati = daily motion of śīghroccha – true mean daily motion of the planet.

Rationale by Sūryadeva Yajvā- Since

True daily motion = śīghrocchagati - sphuṭakendragati, and

sphuṭakendragati =

sphuṭa sphuṭakendragati =

=

Hence the rule.

Sūryadeva Yajvā explains as follows: "Here in the case of śīghra-correction the position is as follows: When the Śīghroccha and the true mean planet are equal, then the true-mean planet itself is the true planet. This is the point from where difference between the true-mean and the true planets begins to appear. From that point of equality, the true-mean planet and the Śīghroccha each, in a civil day, move eastwards through a distance equal to their own daily motions. Now the Śīghroccha being fast and the true-mean planet slow, the true-mean planet, having moved towards the east or west of the point of its orbit (kakṣāvṛtta) occupied by it that day by a distance equal to the difference between daily motions of the true mean planet and the Śīghroccha, appears to hang down (by that distance) towards the west. This is why the daily motion of the Śīghroccha minus the daily motion of the true-mean planet gives the daily motion of the Śīghrakendra. And similarly every day by substracting the daily motion of the true-mean planet from the daily motion of the Śīghroccha one gets the daily motion of the Śīghrakendra. Following the method of planetary correction, having found out the Śīghraphala corresponding to the daily motion of the (Śīghra) Kendra and applying it to the daily motion of the true-mean planet positively or negatively (as the case may be) one gets the true daily motion of the planet. Or, alternatively, the daily motion of the Śīghrakendra itself having made true and then substracting it from the daily motion of the Śīghroccha one gets the true daily motion of the planet. Here, the Āchārya has taken recourse to the second method. Hence the proportion intended by Āchārya is: When the concentric (kakṣāvṛtta) yields this Śīghrakendragati what will the Eccentric yield? This is inverse proportion, because when the hypotenuse (Śīghrakarṇa) increases the Śīghrakendragati decreases and when the hypotenuse decreases the Śīghrakendragati increases. Hence the Śīghra divisor is the abridged true hypotenuse (apavartita sphuṭakarṇa) and the true vyāsa is the abridged radius. This has already been stated. Therefore on multiplying the Śīghrakendragati by the vyāsa and dividing by the (śīghra) divisor which is the requisition, one gets the true daily motion. When the result obtained (from the division) is greater, substraction is made reversely and the remainder obtained is the retrograde motion (vakragati). Here substraction of one-twelfth of the Śīghraphala has been prescribed from the sphuṭa-vyāsa assumed as the argument in the place of the radius; one should understand that this has been done to effect contraction in the kendrabhukti, which is the multiplicand, depending on the contraction produced while finding the Rsine of the

minutes of the bhujaphala, because even by contracting the multiplier the multiplicand is contracted. This is why the Kendra-bhoga (= kendrabhukti) which is the multiplicand is multiplied by sphuṭa-vyāsa minus one twelfth of the Śīghraphala."
Chitrabhānu (AD 1350), in his Karaṇāmṛta, has prescribed the following rule for finding the true daily motion of a planet-

True daily motion = Śīghragati –

इति लघुमानसे स्फुटगत्यधिकारस्तृतीयः। Thus ends chapter 3 on True motion in Laghumānasa.

अथ प्रकीर्णकाधिकारः चतुर्थः (Chapter IV-Miscellaneous Topics)

ग्रहणसमागमादीनां गणितवेधसाम्यर्थं चन्द्रस्य तद्भुक्तेश्च द्वितीय कर्म

इन्दुच्चोनार्ककोटिघ्ना गत्यंशा विभवा (११) विधोः। गुणो व्यर्केन्दु दोःकोट्यो रूप(१) पञ्चा(५) प्तयोः क्रमात्॥१८॥

फले शशाङ्कतद्भुत्योर्लिप्ताद्ये स्वर्णयोर्बधे। ऋणं चन्द्रे धनं भुक्तौ स्वर्णसाम्यबधेऽन्यथा॥१९॥

Second correction for the Moon (Evection plus part of Moon's equation of the centre)
Multiply the degrees of the Moon's (true) daily motion as diminished by 11 by the Rcosine of the (true) longitude of the Sun minus the longitude of the Moon's apogee. This is the multiplier of the Rsine and the Rcosine of the (true) longitude of the moon diminished by that of the Sun, divided by 1 and 5 respectively. The results (thus obtained) are the corrections, in terms of minutes of arc, for the moon and its true daily motion, respectively. If in the above product (one) factor is positive and the other negative, the correction for the Moon is substractive and that for its true daily motion additive. If both are of like signs, both positive or both negative, the corrections are to be applied contrarily.

Let S, M, and U respective denote the true longitudes of the Sun, Moon and the Moon's apogee (mandoccha). Then correction for the Moon

= $8^0 8'$ cos (S-U) [Moon's true daily motion in degrees-11] X $8^0 8'$ sin (M-S) (1)

Which is negative or positive according as $8^0 8'$ cos (S-U) and $8^0 8'$ sin (M-S) are of unlike and like signs; and the corresponding corrections for the Moon's true daily motion

= $8^0 8'$ cos (S-U) [Moon's true daily motion in degrees-11] X $8^0 8'$ cos (M-S)/5
(2)

Which is positive or negative according as $8^0 8'$ cos (S-U) and cos (M-S) are of unlike or like signs. This correction is meant to be applied to the Moon's true longitude and Moon's true daily motion, respectively, in computing the eclipses, rising and setting of the Moon, elevation of the Moon's horns, and Moon's conjunction with the planets etc. in order to achieve equality of computation and observation, but not in finding tithi, karaṇa, nakṣatra and yoga.

It is to be noted that the degrees and minutes obtained from (1) and (2) are to be treated as minutes and seconds; and these minutes and seconds are to be applied to the Moon and its true daily motion, respectively.

Expression (2) is clearly an approximate value of the differential of (1); for
[$8^0 8'$ sin (M-S)] = $8^0 8'$ cos (M-S). [M-S]/R, R being the radius
=

The term involving the differential of cos (S-U) being neglected.

If, for the sake of simplicity, the Moon's mean daily motion viz. 790' 35" be taken in place of the Moon's true daily motion, correction (1) simplifies to

$8^{0}8' \times 8^{0}8' \times 2^{0}11' \cos (S-U) \sin (M-S) = 66^{0}9' \times 2^{0}11' \cos (S-U) \sin (M-S)$

$= 144^{0}26' \cos (S-U) \sin(M-S)$ … (3)

Treating degrees as minutes and minutes as seconds, the correction envisaged is equivalent to

$144'26' \cos (S-U) \sin (M-S)$

Identification of the correction-

According to modern astronomy, the principal terms of the lunar correction are given by the expression

$377' \sin (nt - \alpha) + 13' \sin 2 (nt - \alpha) + \ldots + 76\ \alpha \sin [2(nt -S) - (nt-\alpha)] + 40' \sin 2 (nt - S) + \ldots$

Where nt is the Moon's mean longitude, α the longitude of the Moon's perigee, and S the Sun's longitude. The accurate values of the coefficients are 377'19".06, 12'57".11, 76'26" and 39'30".

In this expression, $377' \sin (nt - \alpha)$ is called the equation of the centre,

$76\ \alpha \sin [2 (nt -S) - (nt-\alpha)]$ is called the evection

and $40' \sin 2 (nt - S)$ is called the variation.

The early Hindu astronomers recognized only the equation of the centre (mandaphala) but instead of taking its value to be $377' \sin (nt - \alpha)$ took its value to be $301' \sin (nt - \alpha)$. So splitting the term $377' \sin (nt - \alpha)$ into two parts $301' \sin (nt - \alpha)$ and $76' \sin (nt - \alpha)$, the above expression may be written as

$301' \sin (nt - \alpha) + 13' \sin 2 (nt - \alpha) + \ldots$

$+ 76' \sin (nt - \alpha) + \sin [2 (nt - S) - (nt - \alpha)] + \ldots + 40' \sin 2 (nt - S) + \ldots$

Or, $301' \sin (nt - \alpha) + 13' \sin 2 (nt - \alpha) + \ldots 152 \cos (S - \alpha) \sin (nt - \alpha) + 40' \sin 2 (nt - S) + \ldots$

Or, in the notation of formula (1),

$301' \sin (M - U) + 13' \sin 2 (M - U) + \ldots + 152' \cos (S - U) \sin (M - S) + 40' \sin 2 (M - S) +$ (4)

Comparison of expression (3) with (4) shows that the expression (3) is analogous to the term $152' \cos (S - U) \sin (M - S)$ of the expression (4), which is a combination of two corrections, viz. part of the equation of the centre and the evection. The only difference is that in place of the coefficient 152' in expression (4), the expression (3) has 144'26".

Mañjula's correction, therefore, is a sum of two corrections, viz.

(i) $76' \sin (M - U)$, which forms that part of the Moon's equation of the centre which was not noticed by the earlier Hindu astronomers, and

(ii) $144'26'' \cos (S - U) \sin (M - S)$, the evection, which too was not noticed by the earlier Hindu astronomers.

It is Mañjula who, for the first time in India, took these two corrections into account. Astronomer Yallaya gives the credit of the discovery of these corrections to Vaṭeśvara (AD 904), but so far we have not been able to confirm the statement of Yallaya.

The correction stated by Mañjula, therefore, is meant to account for the combined effect of the Moon's residual equation of the centre and the evection.

This correction vanishes when the Sun and Moon are in conjunction. That is the reason why it remained undetected by the early Hindu astronomers, who checked the accuracy of the Moon's position by observation at the time of its conjunction with the Moon.

In Greek Astronomy

The Greek astronomer Claudius Ptolemy (c. AD 100 to c. AD 175) was aware of this correction. He constructed an instrument by means of which he observed the Moon in all positions of its orbit and found

(i) that the computed positions of the Moon were generally different from the observed ones, the maximum amount of this difference noted by him being 159', and

(ii) that the difference between the observed and computed positions of the Moon attained its maximum when M – S equaled 90^0 and S – U was either zero or 180^0, and that it vanished altogether when M – S equaled zero or 180^0.

Ptolemy, however, did not give a formula for this correction of the type given by Mañjula.

In later Hindu works-

This correction reappears exactly in the same form in the Karaṇa-kamala-mārtaṇḍa of Daśabala (AD 1058), evidently under the influence of Mañjula. Subsequently, it appears in different but equivalent forms in the Siddhānta-śekhara of Śrīpati (c AD 1039), the Tantra-sangraha of Nīlakaṇṭha (AD 1500), the Uparāga-kriyākrama of Nārāyaṇ (AD 1563), the Karaṇottama of Achyuta (d. AD 1621), and the Siddhānta-darpaṇa of Sāmanta Chandra Śekhara Singh (AD 1869).

Remarks by A.K. Upadhyay-(1) Prof. K.S Shukla has rightly remarked that this correction was not observed as it vanishes when Sun and Moon are in conjunction. Sāmanta Chandra Śekhara Singh in his Siddhānta-darpaṇa, chapter 6 also has remarked this in ornamental language- तुङ्गान्तरं पाक्षिक नामधेयं फलं
दिगंशाख्यमथस्तुरीयम्।
क्रमेण वक्ष्यामि निरीक्ष्य यत्नाच्चित्रां गतिं रात्रिपतेश्चिराय॥६॥
स्थलीषु जङ्गभ्यत एव यद् वद् भुजङ्ग ऋज्वी गतिमेव गर्त्ते।
सदोच्च कर्षातिग एवमिन्दुस्तत्साम्य मागच्छति पर्व सन्धौ॥१४॥
तत्राप्य तुङ्गान्तर पाक्षिके स्यात् सूक्ष्मे दिगंशाख्य फलं यथाहेः।
मताल्पता स्वगतिर्विलेऽपि पार्श्वद्वय स्पर्श दृढा दृढीत्वात्॥१५॥
तिथावुड़ौ द्वित्रिपल प्रभेदो वेद्यः परं विश्वसृजानचान्यैः।
श्रेयात् स तत् शक्र (१४) घटी प्रभेदात् समुद्धरेत् सार मरारतो हि॥३१॥
यदि च लम्बन संस्कृत खेटतस्तिथि मुखानयनं परिचोद्यते।
वधिर तर्हि तव श्रुति गोचरं विवथमेव हि लम्बन शासनम्॥४०॥
अतः कुमध्यात् गत खार्क सूत्रे दृक् तुल्यतामेति नभश्चरो यः।
स एव शुद्धः परमार्थतः स्यात् स्फुटस्ततोऽन्ये विहगास्त्व तथ्याः॥४१॥
भूपृष्ठ देशानां भिन्नाः मध्यमेव यतः समम्। तत्तुल्य खेचरानीतं तिथ्यादेववरं ततः॥४२॥
भास्कराचार्य -लिप्ताविधोरर्कमही (११२)मिता मे दृग्गोचराः प्रत्यहमीक्षितस्य।
कदम्बगोला गत सूत्र पाते क्रान्तौ धनर्णत्वजुषो भमध्यात्॥४४॥
ब्राह्मस्फुटसिद्धान्ते च-ब्रह्मोक्तं ग्रह गणितं महता कालेन यत् खिलीभूतम्।
अभिधीयते स्फुटं तज्जिष्णुसुत ब्रह्मगुप्तेन। इति॥४६॥
लिप्ता विधोरर्क महीति पद्यात् भमध्यता स्याद् विषुवापयस्य।
तदाप्य बीजोपनयानुमेयं विक्षेपमन्त्यं कुवसुद्वि (२८१) लिप्ताम्॥४७॥
यतो विधोः सत्रिभ सायनस्य क्रान्तिज्यका खाद्रिगुणेन्दु (१३७०) तुल्या।

तद् बाण (२८१) निघ्नी त्रिगुणो (३४३८) द्धृतासं धनर्ण दृक्कर्म भुजेश (११२) लिप्तम्॥४८॥
आयाति तद्वीक्ष्य तदुक्तमेतत् बोध्यं कदम्ब ध्रुव सूत्रमध्ये।
सम्भाव्यते यद्यरिवत् श्रुतोक्ता दृक्कर्मतो भिन्नमितीह बीजम्॥४९॥
तदापस्थाद्य विधोर्बमध्ये स्यादत्र कुत्राप्युडु चक्रवृत्ते।
तुङ्गान्तरं तत्फलमन्त्यमेव सूर्येन्दु (११२) तद्बीज पलं तदात्वो॥५०॥
खाङ्गेन्दु (१६०) लिप्तं चिरकालतोऽभूत्तद् वृद्धि ह्रासावुररीक्रियेताम्।
इत्यादि पूर्वोक्तिभिरेव सिद्धं बीजैः स्वकालाक्षि समैः स्फुटत्वम्॥५१॥
समाः सहस्रान्तर एष्यकाले प्रोक्तक्रमेन प्रथमस्फुटेन्दोः।
दृक् चन्द्रतो लप्स्यत एव यावान् भेदः स तद् बीजमितिप्रमेय॥५२॥
षट् षष्टि (६६) दण्डाभ्यधिका तिथिर्या कृत्स्ना पराह्णद्वयमश्नुते सा।
सूक्ष्मैव नान्या तु तथा विधास्यात् षोढ़ाभिधा हि स्मृतिषु प्रसिद्धा॥५३॥
सायाह्न मात्र स्पृग्महि पूर्वे परे दिनार्द्धात् पुरतो गता चेत्।
तत् श्राद्धमुक्तं कुतपे परेद्युः स्मृत्यात्र सूक्ष्मैव मता तिथिः सा॥५४॥
यथाह गौतमः-पूर्वाह्ने चेत् प्रतिपदो भूतो सायम मा यदि।
आरम्भ कुतपे श्राद्धं रोहणं न तु लङ्घयेत्। इति ॥५५॥
सप्तम्या तिथित्रयक्षयघटीर्दृष्टा रसोनाः (६) पुनः षोढ़ा भेद विरोध शङ्कितहृदां मा भूदिहा नादरः।
सप्तम्यादिषु (३) पञ्चधान्यतिथिषु द्विःषट्सु (१२) षोढ़ेति चेत्,
तात्पर्यं स्मृतिजं विचिन्त्यमिहदृक् सिद्धैर्नकापिक्षतः॥५६॥
मध्ये पक्षमिवेन्द्र (१४) सङ्ख्यमघटी भेदश्च पक्षान्तयोः स्याश्चेत् स्थूल तदा ग्रहणयोर्भूरि प्रभेदे क्षणात्।
प्राञ्चो लोकभियापि सूक्ष्म तिथिमन्वेष्टुं व्यधास्यन् श्रमं सर्वेर्भेन्दु युतेरनादृततया मन्ये तदीक्षां जहुः॥५७॥

This explains reasons of 4 corrections to Moon's motion and logic of their names- Manda, Tungāntara, Pākṣika, and Digamśa. These were not necessary at time of eclipse, so these were ignored by earlier Āchāryas. However, its knowledge is evident from rules for śrāddha (last rites). Without special corrections due to attraction of Sun on Moon, 1 Tithi will vary from 54 to 65 daṇḍas, i.e. it can be 5 more or 6 less than the mean of 60 daṇḍas in a solar day. But smṛtis like that of Gautama gives rules which indicate that tithi can be of 51 daṇḍas also. The rule is: if the tithi just touches start of sāyāhna and is over before Kutapa muhūrtta (24 minutes before and after local true noon), then śrāddha should be done next day. Here, 1 tithi = sāyāhna (6 daṇḍas) + night (30 daṇḍas) + half day(15 daṇḍas) = 51 daṇḍas.

(2) Another reason has been indicated in quotation from Brahmagupta. Brahmā has made a long term calendar. In such calculation, corrections within half month are not to be mentioned.

(3) Pañchānga Committee of 1930-31 under Paṇḍit Dinanath Shastri Chulet of Indore set up by king Yashavanta Rao Holkar has also indicated several quotes from smṛtis to show tithi variation from 50 to 69 daṇḍas). It had also indicated a rule of variation of Tithis in a fortnight quoted by Kamalākara Bhaṭṭa in his Nirṇaya-sindhu from Skanda-purāṇa. As it indicated accurate calculation in ancient India, it was removed by William Jones from printed edition of Skanda-purāṇa.
षोडशेऽह्न्यभीष्टेष्टिर्मध्या पञ्चदशेऽहनि। चतुर्दशे जघन्येष्टिः पापापञ्चदशेऽहैरित्यत्र॥

सप्तदिनात्मकः पक्षः प्रतिषेधे उक्तः। (काल माधव, प्रकरण ४)
ज्योतिर्निबन्ध-पक्षस्य मध्ये द्वितिथी पतेतां तदा भवेद्रौरव कालयोगः।
पक्षे विनष्टे सकलं विनष्टरित्याहुराचार्यवराः समस्ताः॥१॥
उपनयनं परिणयनं वेश्मारम्भादि कर्माणि॥ यात्रां द्विक्षयपक्षे कुर्यान्न जिजीविषुः पुरुषः॥
चण्डेश्वर-त्रयोदशदिने पक्षे विवाहादि न कारयेत्। गर्गादि मुनयः प्राहुः कृते मृत्युस्तदा भवेत्॥१॥
महाभारत, भीष्म पर्व-चतुर्दशीं पञ्चदशीं भूतपूर्वां च षोडशीम्। इमां त्वमभिजानेहमावस्यां त्रयोदशीम्॥
वराहमिहिर, बृहत् संहिता (४/३१)-शुक्ले पक्षे सम्प्रवृद्धे प्रवृद्धिं ब्रह्मक्षत्रं याति वृद्धिं प्रजाश्च।
हीने हानिस्तुल्यता तुल्यतायां कृष्णे सर्वं तत् फलं व्यत्ययेन॥
मुहूर्त चिन्तामणि-विश्व (१३) घस्रेऽपिपक्षे॥४८॥ मुहूर्त सिन्धु भी।
कालमाधव में बौधायन की उक्ति-
यत्रोपवसथं कर्म यजनीयात् त्रयोदशम् (१३)। भवेत् सप्तदशं (१७) वापि तत् प्रयत्नेन वर्जयेत्॥
कमलाकर भट्ट, निर्णय सिन्धु, तिथि-निर्णय प्रकरण-तिथेर्वृद्धिक्षययोर्मानमप्युक्तं स्कन्देन-
नागो (८) द्वादश (१२) नाडीभिर्दिक्(१०) पञ्चदशभिस्तथा (१५)॥
भूतो (१४) ऽष्टादश (१८) नाडीभिर्दूषयत्युभये तिथिम्॥१॥
वृद्धिकाशयौ स्तः परमौ तिथौ सदा व्यर्धा रसाः (५ १/२)॥ सर्ध रसा (६ १/२) श्च नाडिकाः॥
स नेमिशैला (७ १/४) विपदोऽष्टमा (७ ३/४) स्तथा निरङ्घ्रिरन्ध्रि (८ ३/४) सपदा नव (९ १/४) तस्मात्॥२॥
Half month of 13 or 17 days means that 1 tithi is of 13/15 days = 52 daṇḍa, or 17/15 days = 68 daṇḍas. This is average, a particular tithi can be from 50 to 69 daṇḍas.
(3) All astronomy texts give location of towns on globe separated by 90^0 longitude with reference at Ujjain- Yamakoṭipattana 90^0 east (south west tip of Newzealand with same south latitude as Yama star, It is nearest to Yama-dvīpa (yamala =2) which is Antarctica with 2 land masses. In cylindrical projection of map, or pyramid projection, its scale will be infinite, so it was called Ananta), Siddhapura 180^0 east (a gate was constructed here by Brahmā to mark end of east direction-Vālmīki Rāmāyaṇa, Kiṣkindhā kāṇḍa, 40/54, 64) , Romakapattana 90^0 west (where Maya-Asura revised text of Vivasvān, father of Vaivasvat Manu). This is not possible without accurate survey of the whole globe. Only after survey of globe, we can find distance of Moon by parallax from 2 places whose distance can be known only by global survey. That is by sighting nakṣatras, so it is called nakśā. All purāṇas tell triangular shape of India in south, but reek authors thought it to be rectangular which shows lack of their knowledge. All astronomy, works of Greeks were written at Egypt only. Appolonius and Herodotus had come to India for study. But no outsider has ever gone to Greece for study, they could go only as a slave. Measures of solar system, galaxy abound in Vedas and astronomy texts which indicate accurate global measurements in astronomy in past. Purāṇas give 4 cardinal towns of Indra-Vasvaukasārā, Soma-Vibhāvarī (90^0 east), Varuṇa-Sukhā (180^0 east), and Yama-Sanyamanī (90^0 west) separated by 90^0 longitude. These could be at junction of Talas or could be earlier division at time of Svāyambhuva Manu.
References-(a) Megasthenes: Indika
http://projectsouthasia.sdstate.edu/docs/history/primarydocs/Foreign_Views/GreekRoman/Megasthenes-Indika.htm
FRAGMENT I OR AN EPITOME OF MEGASTHENES. (Diod. II. 35-42.)

(35.) India, which is in shape quadrilateral, has its eastern as well as its western side bounded by the great sea, but on the northern side it is divided by Mount Hemodos from that part of Skythia which is inhabited by those Skythians who are called the Sakai, while the fourth or western side is bounded by the river called the Indus, which is perhaps the largest of all rivers in the world after the Nile. The extent of the whole country from east to west is said to be 28,000 stadia, and from north to south 32,000.

(b) Shape ofr India-मत्स्य पुराण, अध्याय ११४-भारतस्यास्य वर्षस्य नव भेदान् निबोधत।७।
इन्द्रद्वीपः कशेरुश्च ताम्रपर्णो गभस्तिमान्। नागद्वीपस्तथा सौम्यो गन्धर्वस्त्वथ वारुणः।८।
अयं तु नवमस्तेषं द्वीपः सागरसंवृतः। योजनानां सहस्रं तु द्वीपोऽयं दक्षिणोत्तरः।९।
आयतसु कुमारीतो गङ्गायाः प्रवहावधिः। तिर्यगूर्ध्वं तु विस्तीर्णः सहस्राणि दशैव तु।१०।
यस्त्वयं मानवो द्वीपस्तिर्यग् यामः प्रकीर्तितः। य एनं जयते कृत्स्नं स सम्राडिति कीर्तितः।१५।

(c) Cardinal towns of world-(*सूर्य सिद्धान्त १२/३८-४२)-*
भूवृत्तपादे पूर्वस्यां यमकोटीति विश्रुता। भद्राश्ववर्षे नगरी स्वर्णप्राकारतोरणा॥३८॥
याम्यायां भारते वर्षे लङ्का तद्वन् महापुरी। पश्चिमे केतुमालाख्ये रोमकाख्या प्रकीर्तिता॥३९॥
उदक् सिद्धपुरी नाम कुरुवर्षे प्रकीर्तिता (४०) भूवृत्तपादविवरास्ताश्चान्योन्यं प्रतिष्ठिता (४१)
तासामुपरिगो याति विषुवस्थो दिवाकरः। न तासु विषुवच्छाया नाक्षस्योन्नतिरिष्यते ॥४२॥
विष्णु पुराण (२/८)-मानसोत्तरशैलस्य पूर्वतो वासवी पुरी।
दक्षिणे तु यमस्यान्या प्रतीच्यां वारुणस्य च। उत्तरेण च सोमस्य तासां नामानि मे शृणु॥८॥
वस्वौकसारा शक्रस्य याम्या संयमनी तथा। पुरी सुखा जलेशस्य सोमस्य च विभावरी।९।
शक्रादीनां पुरे तिष्ठन् स्पृशत्येष पुरत्रयम्। विकोणौ द्वौ विकोणस्थस्त्रीन् कोणान्द्वे पुरे तथा।॥१६॥
उदितो वर्द्धमानाभिरामध्याह्नात्तपन् रविः। ततः परं ह्रसन्तीभिर्गोभिरस्तं नियच्छति॥१७॥

(d) Extent of solar wind upto Uranus orbit = 3000 sun diameters-
यजुर्वेद (१/१)-ईषे त्वा ऊर्जे त्वा वायवस्थः = Energy in flow (*vāyu*) is called *īśā*.
विष्णु पुराण (२/८/२)-योजनानां सहस्राणि भास्करस्य रथो नव। ईषादण्डस्तथैवास्य द्विगुणो मुनिसत्तम॥ = In *Ratha* (body or extent) of solar system, *Īṣā-daṇḍa* is 9000 *yojanas*.

(e) Size of solar system-Purāṇas give meaure as ratha of sun of 157 lakh yojanas (sun-diameter).
विष्णु पुराण (१/८/३)-सार्धकोटिस्तथा सप्त नियुतान्यधिकानि वै। योजनानां तु तस्याक्षस्तत्र चक्रं प्रतिष्ठितम्॥ (f) Size of galaxy-सूर्य सिद्धान्त (१२)- भवेद् भकक्षा तिग्मांशो र्भ्रमणं षष्टिताडितम्।
सर्वोपरिष्टाद् भ्रमति योजनैस्तैर्भमण्डलम्॥८०॥
ख-व्योम-खत्रय-ख-सागर-षट्क-नाग-व्योमा-ष्ट-शून्य-यम-रूप-नगा-ष्ट-चन्द्राः।
ब्रह्माण्ड संपुटपरिभ्रमणं समन्तादभ्यन्तरा दिनकरस्य करप्रसाराः॥९०॥
This is 1.87 x 10^{16} yojanas, here it is Bha-yojana = 27 x Bhū-yojana = 214 kms. This is about 13000 light years diameter. Kaṭhopaniṣad gives ½ X 10^{17} dhāma yojanas (half degree of equator = 55.5 kms) as circumference, or 9700 LY diameter. NASA estimate was 100000 LY in 1995 and 95000 in 2005.
कठोपनिषद् (१/३/१)-ऋतं पिबन्तौ सुकृतस्य लोके गुहां प्रविष्टौ परमे परार्धे।
छायातपौ ब्रह्मविदो वदन्ति, पञ्चाग्नयो ये च त्रिणाचिकेताः॥

Verse 20-देशान्तरसंस्कारः-Correction for local longitude
अवन्तिसमयाम्योदग्रेखापूर्वापराध्वना। ग्रहगत्यंश **षष्ट्यं**शो हतो लिप्ता स्वृणं धनम्॥२०॥

By the distance (in yojanas) of the local place, east or west of the meridian of Avanti, multiply the 60 part of the degrees of the planet's daily motion; sustract the resulting minutes from or add them to the longitude of the planets (according as the local place is to the east or to the west of the meridian of Avanti).

That is, longitude correction = mins.

Where d denots the distance, in yojanas, of the local place from the Hindu prime meridian (i.e. the meridian of Avantī or Ujjayinī), and m the planet's daily motion in terms of degrees, - or + sign being taken according as the local place is to the east or west of the prime meridian.

Mañjula takes earth equator as 3600 yojanas and uses the ratio

=

The rule is approximate as local circumference has been taken as equatorial circumference of the earth. Yallaya gives a different reading of the text-

अवन्ती समयाम्योदग् रेखापूर्वपराध्वना। हता भुक्तिः खखाष्टाब्धि (४८००)हृता लिप्तास्वृणं धनम्॥

= By the distance (in yojanas) of the local place, east or west of the meridian of Avanti, multiply the daily motion of the planet and divide by 4800; substract that from or add that to the minutes of the planet's longitude (according as the local place is to the east or to the west of the meridian of Avanti).

Here the equatorial circumference of the earth has been assumed to be 4800 yojanas.

The Hindu prime meridian, by common consent, is the meridian that passes through Avantī or Ujjayinī (modern Ujjain). According to the commentator Praśastidhara, these places are situated on it-Lankā, Kumārikā, Kāñchī, Pāṭalī, Siddhapurī, Vatsagulma, Ujjayinī, Lohitaka, Kuru, Yamunā, and Meru. Lankā is a hypothetical place in 0 latitude and 0 longitude. Kumārikā is the same as Kanyā Kumārī (modern Cape camorin). Kāñchī is also called Kanjivaram. Vatsagulma is Basim. Lohitaka is Rohatak. Kuru is Kurukṣetra. Yamunā is Yamunānagara. Meru is north pole. Pāṭalī and Siddhapurī are unidentified.

Mean daily motions stated by Yallaya and Praśastidhara are-

Planet	mean daily motion	Planet	mean daily motion
Sun	59'8"	Venus	96'8"
Moon	790'35"	Saturn	2'0"
Mars	31'26"	Moon's apogee	6'41"
Mercury	245'32"	Moon's ascending node	-3'11"
Jupiter	5'00"		

तिथि-करणनक्षत्र-योगानयनम्

व्यर्केन्दोस्तिथितिथ्यर्धे ग्रहाद्भान्यनुपाततः। योगाश्चन्द्रार्कसंयोगात्तदाद्यन्तौ स्वभुक्तितः॥२१॥

Tithi, Karaṇa, Nakṣatra, and Yoga

Compute the Tithi and the Karaṇa from Moon's longitude minus Sun's longitude, the Nakṣatra from the planet's longitude, and the Yoga from Moon's longitude plus Sun's longitude; and the time of their beginning and end from their own daily motions, by applying proportion.

Comments-The tithi, vāra (day), nakṣatra, karaṇa, and yoga constitute the five elements of the Hindu pañchānga. Let S be the Sun's longitude and M the Moon's longitude. Also let d be the difference and s the sum of daily motions of the Sun and

Moon. Then the tithi, karaṇa, nakṣatra and yoga and their computation may be described as follows-

Tithi-A lunar month, which is defined in Hindu astronomy as the period from one new moon to the next, is divided into 30 parts called tithis (or lunar days). Of these 30 tithis, 15 fall in the light fortnight (śukla pakṣa) and 15 in the dark fortnight (kṛṣṇa pakṣa). When M – S = 0, it is the new moon and beginning of the first tithi; when M – S = 12^0, the first tithi ends and the second begins; when M – S = 24^0, the second tithi ends and the third begins; and so on. The fifteen tithis of the light fortnight are numbered as 1, 2, 3, ……., 14, 15 and the fifteen tithis of the dark fortnight are numbered as 1, 2, 3, ……., 14, 30. The first tithi of each fortnight is called Pratipad or Pratipadā, the fifteenth tithi of the light fortnight is called Pūrṇimā or Pūrṇamāsī, and the thirtieth tithi of the month is called Amā, Amāvasyā, or Amāvāsyā.

To compute the tithi, reduce M – S to minutes of arc and divide by 720 (720' = 12^0 being the measure of a tithi). The quotient of the division gives the number of tithis elapsed since the beginning of the lunar month. The remainder of the division multiplied by 60 and divided by d gives the ghaṭīs etc elapsed since the beginning of the current tithi.The same remainder substracted from 720, when multiplied by 60 and divided by d gives the ghaṭīs etc. to elapse before the end of current tithi.

Karaṇa-A karaṇa is half of a tithi and likewise there are 60 karaṇas in a lunar month. The measure of a karaṇa is 360' minutes of arc. The first karaṇa begins when M – S = 0; the second when M – S = 6^0, the third when M – S = 12^0; and so on. The first karaṇa is called Kimstughna, then a cycle of 7 karaṇas called Bava (or Baba), Bālava, Taitila, Gara, Vaṇija, and Viṣṭi (respectively) repeats itself 8 times. These 7 karaṇas are called movable karaṇas. Of these karaṇas, Viṣṭi (also called Bhadrā) is considered to be inauspicious and no auspicious deed is done in its duration. Then the 58th karaṇa is called Śakuni, 59 Nāga, and the last 60 is Chatuṣpada.

To compute the karaṇa, reduce M – S to minutes of arc and divide by 360. The quotient gives the number of karaṇas elapsed. The remainder multiplied by 60 and divided by d gives the ghaṭīs etc elapsed since the beginning of the current karaṇa.The same remainder substracted from 360, when multiplied by 60 and divided by d gives the ghaṭīs etc. to elapse before the end of current karaṇa.

Nakṣatra-Beginning with the first point of nakṣatra Aśvinī (or star Zeta Piscicum), the ecliptic is divided into 27 equal parts, each equal to 800 minutes of arc. These parts are called nakṣatra and are named –(1) Aśvinī, (2) Bharaṇī, (3) Kṛttikā, (4) Rohiṇī, (5) Mṛgaśirā, (6) Ārdrā, (7) Punarvasu, (8) Puṣya, (9) Āṣleṣā, (10) Maghā, (11) Pūrvā-Phālgunī, (12) Uttarā-Phālgunī, (13) Hasta, (14) Chitrā, (15) Svātī, (16) Viśākhā, (17) Anurādhā, (18) Jyeṣṭhā, (19) Mūla, (20) Pūrva-āṣāḍha, (21) Uttara-āṣāḍha, (23) Śravaṇa, (24) Dhaniṣṭhā, (25) Śatabhiṣak, (25) Pūrva-Bhādrapadā, (26) Uttarā-Bhādrapadā, and (27) Revatī.

To compute the nakṣatra, reduce the longitude of the desired planet to minutes and divide it by 800'. The quotient gives the number of nakṣatras passed over by the planets. The remainder divided by the daily motion of the planet gives the day etc. elapsed since the planet entered into the current nakṣatra. The same remainder substracted from 800, when divided by the daily motion of the planet, gives the days etc, to elapse before the planet enters into the next nakṣatra. The Pañchāngas give the Moon's nakṣatra.

Yoga-The yogas are also 27 in number and are named-(1) Viṣkambha, (2) Prīti, (3) Āyuṣmān, (4) Saubhāgya, (5) Śobhana, (6) Atigaṇḍa, (7) Sukarmā, (8) Dhṛti, (9) Śūla, (10) Gaṇḍa, (11) Vṛddhi, (12) Dhruva, (13) Vyāghāta, (14) Harṣaṇa, (15) Vajra, (16) Siddhi, (17) Vyatīpāta, (18) Varīyāna, (19) Parigha, (20) Śiva, (21) Sādhya, (22) Siddha, (23) Śubha, (24) Śukla, (25) Brahmā, (26) Indra, and (27) Vaidhṛti.

The measure of each yoga is 800' minutes of arc. The first yoga begins when S + M = 0, the second when S + M = 800', the third when S + M = 1600', and so on. To compute the yoga, reduce S + M to minuts of arc and divide by 800. The quotient gives the number of yoga elapsed since the beginning of the current yoga, and the remainder multiplied by 60 and divided by 800 gives the ghaṭīs etc. The same remainder substracted from 800, when multiplied by 60 and divided by 800, gives the ghaṭīs etc to elapse before the end of the current yoga.

इति लघुमानसे प्रकीर्णकाधिकारः चतुर्थः। (Thus ends chapter 4 in Laghumānasa)

अथ त्रिप्रश्नाधिकारः पञ्चमः (Chapter V-The three probems)

The astronomers are not unanimous regarding the three problems. According to Bhaṭṭotpala, the three problems relate to lagna (rising point of the ecliptic), kāla (time corresponding to lagna) and chhāyā (gnomonic shadow). According to Bhūdhara, they relate to lagna, chhāyā and chara (twice the ascensional difference). But generally, they are supposed to relate to dik (cardinal directions), deśa (latitude of the local place) and kāla (time). In te present chapter, Mañjula deals with chara, lagna and chhāyā.

मेषादि राशीनां चरविनाड्यानयनम्

नख (२०)घ्ना विषुवच्छाया स्वाक्षं (५)शोना त्रिभाजिता। उदग्विषुवदाद्यर्कभुजराशिगुणश्चरे॥२२॥

Chara or twice the ascensional differences of signs, and Sun's Chara

The equinoctical midday shadow (viṣuvacchhāyā or palabhā) multiplied by 20; that product diminished by 1/5 of itself; and the same product divided by 3: these (three) are the multipliers of the (successive three) signs of the bhuja of the tropical longitude of the Sun, which is measured from the vernal equinox. These multipliers are to be used to find (the vināḍīs of) the Sun's chara (i.e. twice the Sun's ascensional difference).

The commentator Parameśvara says: "This is what has been said (here): Write down the tropical longitude of the Sun for the desired time and find the bhuja thereof. Of the signs of that bhuja, multiply the first by the first multiplier, the second by the second (multiplier), and the third by the third (multiplier). Having multiplied them separately, find their sum. What results are the vināḍīs of the Sun's chara."

Example-The tropical longitude of the Sun is 8 signs 25^0. Find the Sun's chara for a place where palabhā = 6 angulas.

Here Sun's bhuja = 2 signs 25^0. Therefore,

Sun's chara = chara of first sign + chara of second sign + chara of third sign X 25/30 vināḍīs

= 120 + 96 + 40 X 25/30 vināḍīs = 216 + 100/3 vināḍīs = 249 ½ vināḍīs.

The three quantities stated in the text are the charas for the first three tropical signs, viz. Aries, Taurus, and Gemini. That is,

Chara for Aries = 20 X palabhā vināḍīs

Chara for Taurus = 20 X palabhā (1 - 1/5) vināḍīs

Chara for Gemini = 20 X palabhā/3 vināḍīs
The Sun's chara (or chara for the Sun) means the difference between the duration of daylight at the local place and the equator, or twice the Sun's ascensional difference. In general, the chara for a heavenly body is twice the ascensional difference of that heavenly body, i.e. twice the difference between the times of rising of that body at the local place and the local equatorial place.
The charas for the sign Aries means the difference between chara for the last point of Aries and the chara for the first point of Aries. The charas for the sign Taurus means the difference between chara for the last point of Taurus and the chara for the first point of Taurus. Similarly, the charas for the sign Gemini means the difference between chara for the last point of Gemini and the chara for the first point of Gemini.
The term palabhā means the equinoctical midday shadow of a gnomon of 12 angulas (digits). The term viṣuvacchhāyā used in sanskrit text is synonym of palabhā.
The term vināḍī is a unit of time equal to one-sixtieth of a nāḍī or ghaṭī, or 24 seconds. Vināḍī is also called chaṣaka.

मेषादिराशीनामुदयविनाडिकानयनम्

वसुभा(२७८)न्यङ्कगोदस्रा(२९९) स्त्रिदन्ता(३२३)श्च क्रमोत्क्रमात्।
तत्तचरगुणार्धोना मध्यषट्केऽन्यथोदयाः॥२३॥

Oblique Ascensions of the Signs

278, 299, and 323 written in the serial and diminished by the corresponding ascensional differences are the oblique ascensions (in vināḍīs) of the first three signs (Aries, Taurus, and Gemini); the same written in reverse order are the oblique ascensions of the last three signs (Capricorn, Aquarius, and Pisces); the same three numbers written in the reverse and serial orders and increased by the corresponding ascensional differences give the oblique ascensions of the six signs in the middle (viz. Cancer, Leo, Virgo, and Libra, Scorpio, and Sagittarius).
278, 299, and 323 vināḍīs are the right ascensions of the (tropical) signs Aries, Taurus, and Gemini. Or the times of rising at the equator of the (tropical) signs Aries, Taurus, and Gemini, in terms of vināḍīs.
Let a, b, and c vināḍīs be the ascensional differences of the (tropical) signs Aries, Taurus, and Gemini. Then the oblique ascensions (or the times of rising at the local place) of the twelve (tropical) signs are:

Sign	oblique ascensions in vināḍīs	Sign	oblique ascensions in vināḍīs
1. Aries	278 - a	12. Pisces	278 - a
2. Taurus	299 - b	11. Aquarius	299 - b
3. Gemini	323 - c	10. Capricorn	323 - c
4, Cancer	323 + c	9. Sagittarius	323 + c
5. Leo	299 + b	8. Scorpio	299 + b
6. Virgo	278 + a	7. Libra	278 + a

इष्टघटिकाभ्यो लग्नानयनं इष्टलग्नाद् घटिकानयनञ्च

स्वोदयैः प्रश्ननाडीभिर्वर्धितोऽर्कोऽनुपाततः। लग्नं तद्वद्विवृद्धेऽर्के लग्नतुल्ये तु नाडिकाः॥२४॥

Lagna and Iṣṭa Nāḍīs

The (tropical) longitude of the Sun (increased by the signs and parts thereof), calculated by proportion from their own oblique ascensions and the nāḍīs elapsed since sunrise (dyugatanāḍīs) given in the equation, gives the lagna (the longitude of the rising point of the ecliptic). Similarly, the Sun's (given) longitude, being increased until it becomes equal to the lagna, gives the nāḍīs elapsed since sunrise.

This gives the visual methods for finding the lagna and the Iṣṭakāla. Bhāskara-1 has given these methods in greater detail. See Mahābhāskarīya 2/30-32, 33.

The tropical longitude of the lagna having obtained by the above method, the precession of the equinoxes is substracted therefrom to get the nirayaṇa (or sidereal) longitude of the lagna. It is the nirayaṇa longitude that is needed.

दिनमानसाधनम्-व्यस्तं चरविनाडीभिः खाग्नय(३०)स्संस्कृता दिनम्।
नतनाड्यानयनम्-मध्यान्नतनाड्यस्स्युर्दिनार्धद्युदगतान्तरम्॥२५॥

Day-length and Natakāla (Hour angle)

The vināḍīs of the Sun's chara (i.e., wtice the Sun's ascensional difference), being applied reversely to 30 nāḍīs, give the length of the day. The difference between the semi-duration of the day and the day elapsed since sunrise gives the nāḍīs of the Sun's hour angle from midday.

When the Sun is in the northern hemisphere:

Length of day = 30 nāḍīs + twice the Sun's ascensional difference (in vināḍīs),

Length of night = 30 nāḍīs - twice the Sun's ascensional difference (in vināḍīs).

When the Sun is in the southern hemisphere:

Length of day = 30 nāḍīs - twice the Sun's ascensional difference (in vināḍīs),

Length of night = 30 nāḍīs + twice the Sun's ascensional difference (in vināḍīs).

The term 'reversely' in the text is meant to say thet the vināḍīs of the Sun's chara should be added when the sign of the Sun's chara is negative, and substracted when the sign of the Sun's chara is positive, the sign of the Sun's chara being the same as the sign of Sun's bhuja. That is, addition of the vināḍīs of the Sun's chara should be made when the Sun is in the northern hemisphere and substraction when the Sun is in the southern hemisphere.

The hour angle is measured from midday. Before midday, it is east; after midday, it is west.

मध्याह्नच्छायानयनम्
पञ्च(५)घ्नेष्टचरार्धेन पलभाप्तेन संस्कृतात्। आद्याच्चरगुणादह्ना दिगुणेन दिनार्धभा॥२६॥

Midday Shadow

The chara (vināḍīs) of the first sign decreased or increased by 5 times (the vināḍīs of) the Sun's ascensional difference divided by the palabhā, when divided by (the nāḍīs of) the length of day minus 10, gives the midday shadow.

That is, midday shadow =   angulas.

∽ or + sign being taken according as the Sun is in the northern or southern hemisphere.

Rationale-Let ϕbe the local latitude, the Sun's declination, and a, z the sun's altitude and zenith distance at midday. Then

z =   ,

according as the Sun is in the northern or southern hemisphere.

∴ Rsin z =

= (1)
Because = = (2)
∴ midday shadow = =
= , using (1)
= = ,
Because = x earthsine = charārdhajyā
= =
= =
= angulas
= angulas.
Alternative Rationale-
Midday shadow = 12 tan z = 12 tan (ϕ),
(according as the Sun is in the northern or southern hemisphere)
= =
= =
= ,
Because charanāḍīs = = 20. tan . tan
= angulas.
इष्टच्छायानयनम्
विदिग्दिननवाभ्यासान्नतकृत्यंशको युतः। विदिग्दिनशतांशेन गुणोऽसौ व्येकको हरः॥२७॥
तदैक्याच्छङ्कु(१२)वर्गघ्नान्मध्यच्छायागुणाहतेः। कृत्या युतात्पदं यत्स्यात्तस्माच्छेदाप्तमिष्टभा॥२८॥
Shadow for the given time
Add the product of day-length (in terms of nāḍīs) minus 10 and 9, divided by the square of the natakāla (in terms of nāḍīs), to day length (in terms of nāḍīs) minus 10, divided by 100: this is the multiplier, and this diminished by 1 is the divisor. Take the sum of these (multiplier and divisor), multiply that by square of 12, and increase that by the square of the product of the midday shadow and the multiplier. The square-root of that, divided by the divisor, gives the (gnomonic) shadow for the given time. That is:
Desired shadow = angulas,
Where multiplier M = + ,
Divisor D = M – 1.
Rationale-This rule is based on the formula:
Desired shadow = (1)
Since hypotenuse of desired shadow
=
=
Where M =
=
Where ϕ is the local latitude, the Sun's declination, a the Sun's altitude, and R the radius., the Sun being supposed to be in the northern hemisphere.
= =
Because applying cosine formula to the spherical triangle ZPS in which Z is the zenith, P the north pole, S the Sun, arc ZS = 90^0 – a, arc ZP = 90^0 – ϕ, arc PS = 90^0 –, and angle ZPS = N, we have sin a = .

= = , N being in nāḍīs
= = ,
Using Bhāskara 1's formula: sin =
= =
= =
=
Because chara = 2 tan radians = 2 R. tan mins.
= nāḍīs = 20 tan nāḍīs approx.
=
= , where d = day-length in nāḍīs
= = ,
Therefore, from (1) we have
Desired shadow =
=
=
=
=
=
Where M = + , and D = M – 1.
Note-When the Sun is in the southern hemisphere, the rationale is similar.
छायातः छायाकर्णानयनं तस्माच्छाया च-छायार्क(१२)वर्गसंयोगान्मूलं कर्णास्ततोऽपि भा।
Hypotenuse of Shadow-The square-root of the sum of the squares of the shadow and 12 is the hypotenuse of the shadow. From the hypotenuse of the shadow one may derive the shadow (by proceeding reversely).
That is, hypotenuse of shadow =
And shadow =
इष्टच्छायामध्याह्नच्छायाभ्यां नतघटिकासाधनम्-इष्टकर्णः स्वमध्याह्नकर्णान्तरहृतो गुणः॥२९॥
विदिग्दिनशतं(१००)शोनगुणकेन विदिग्दिनात्। नवाहतात् फलं यत्स्यात् तन्मूलं नतनाडिकाः॥३०॥
Natakāla or Hour angle
Divide the hypotenuse of the given shadow by the hypotenuse of the given shadow minuse the hypotenuse of the midday shadow: this is the multiplier. Divide the day-length minus 10, multiplied by 9, by the multiplier as diminished by 1/100 of the day-length minus 10. What is obtained as the square-root of that gives the nāḍīs of the natakāla (hour angle).
That is, Natakāla = nāḍīs
Where M is the multiplier given by
M =
Rationale- We have shown above (under verses 27-28) that
M = +
Therefore, N^2 =
Giving Natakāla N = nāḍīs
इति लघुमानसे त्रिप्रश्नाधिकारः पञ्चमः।
Thus ends chapter 6 in Laghumānasa.
अथ ग्रहयुतिग्रहणद्वयपरिलेखनाधिकारः षष्ठः

Chapter VI-Conjunction of two planets, Eclipses, and their graphical representation
ग्रहयोर्योगस्य गतैष्यज्ञानम्
ग्रहयोरन्तरे स्वल्पेऽनल्पभुक्तेः पुरस्सरः। यदाऽल्पगतिरेष्यस्स्यात्तदा योगोऽन्यथा गतः॥३१॥
Criterion for Conjunction passed or to come
When the difference between the longitude of two planets is small and the slower planet is ahead of the faster planet, (it should be understood that) the conjunction of the two planets is to occur (in near future); in the contrary case, (it should be understood that) the conjunction has already occurred (in the near past).
This criterion relates to the case when the two planets are in direct motion.
When the two planets are in retrograde motion and the lower one has greater longitude, it should be understood that the conjunction has already occurred; in the contrary case, it should be understood that the conjunction is to occur.
When of the two planets, one with greater longitude is retrograde and the other is direct, it should be understood that the conjunction is to occur; if the planet with lesser longitude is retrograde and the other is direct, it should be understood that the conjunction has already occurred.
By the conjunction of two planets is meant the equality of their nirayaṇ (sidereal) longitudes.
ग्रहयोस्समागमकालज्ञानम्
युत्या भिन्नदिशोर्गत्योरन्तरैरेकदिक्कयोः। ग्रहान्तरदिनानि स्युस्तैस्समावनुपाततः।३२॥
Days passed since Conjunction or to pass before Conjunction-Equalization of Longitudes-
By the sum of their daily motion if they are movingin the opposite directions, or by the difference of their daily motin if they are moving in the same directions, divide the difference between their longitudes: then are obtained the days (passed since conjunction or to pass before conjunction). From these days, applying proportion, equalize the longitudes of the two planets.
Śrīpati says: “Dividing the difference of (the longitudes of) the two planets by the difference of their daily motions when both the planets are either direct or retrograde, or by the sum of their daily motion when one planet is direct and the other retrograde, and then adding or substracting, as the case may be, the motions of the two planets, obtained by proportion from the resulting days, the two planets become equal in longitude up to minutes. The resulting motions of the two planets should be substracted from the corresponding planets if the conjunction has already occurred or added to the longitudes of the corresponding planets if the conjunction is yet to occur, provided the planets are both direct; if the planets are both retrograde, the reverse should be done. If one planet is retrograde and the other direct, the resulting motion should be applied reversely in case of the retrograde planet as as stated in the case of the direct one.” (Siddhānta Śekhara 11/12-14)
Śūryadeva Yjavā adds: “This should be done on the basis of true longitudes of the planets. Having thus obtained the time of conjunction, one should find the mean longitudes of the true planets for that time and then convert them into true longitudes. This being done, if they happen to be equal up to minutes, then they are undoubtedly the true planets (for the time of conjunction); if they are not equal up to minutes, the process stated above (in verses 31-32) shoud be repeated again and

again until equality is achieved. The two planets, thus obtained by the successive repetition of the process, are true as well as equal (to each other) up to minutes."

सूर्याचन्द्रमसोर्बिम्बानयनम्

भानोर्बिम्बं रविच्छेदहृताः खखकृताचलाः (७४००)। शशिनः खखभूरामा (३१००)

श्चन्द्रमान्दहरोद्धृताः॥३३॥ Diameters of the Sun and Moon

7400 divided by the Sun's divisor (chheda) is the diameter of the Sun's disc (in terms of minutes); and 3100 divided by the Moon's manda divisor is the diameter of the Moon's disc (in terms of minutes).

That is,

Sun's diameter = minutes = mins,

Where ϕ is the Sun's bhuja.

Moon's diameter = = mins.

Where ϕ is the Moon's bhuja.

Examples-

(1) When Kendra = 0, bhuja =0, and koṭi = 90^0, we have

Sun's diameter = min. = 32' 27"

Moon's diameter = mins. = 30' 40"

(2) When Kendra = 90^0, bhuja = - 90^0 and koṭi = 0, we have

Sun's diameter = min. = 33'2"

Moon's diameter = mins. = 32'

(3) When Kendra = 180^0, bhuja = 0, koṭi = - 90^0, we have

Sun's diameter = min. = 33'40".

Moon's diameter = mins. = 33'21".

Rationale-According to Āryabhaṭa-1,

Sun's linear diameter = 4410 yojanas

And Sun's mean distance = 459585 yojanas,

Therefore, Sun's mean diameter = mins. = or mins. approx.

∴ Sun's true diameter = mins.

Similarly, according to Lalla-

Moon's linear diameter = 320 yojanas

And Moon's mean distance = 34377 yojanas,

Therefore, Moon's mean diameter = mins. = or mins. approx.

∴ Moon's true diameter = mins.

Note-Manda divisors of planets are in verse 3 of chapter 2.

चन्द्रमार्गे छायाग्रहमानानयनम्

छायाग्रहस्सषड्भोऽर्कस्तन्मण्डलकलामितिः। चन्द्रमार्गे शशिच्छेदहृतः खखगुणोरगाः(८३००)॥३४॥

Diameter of Shadow

The longitude of the Sun plus 6 signs is the longitude of the shadow planet. Its diameter in terms of minutes, in the Moon's orbit, is equal to 8300 divided by the Moon's divisor.

The shadow planet (or shadow) is the section of the Earth's shadow cone, at the Moon's distance. It is diametrically opposite to the Sun, so that its longitude is 6

signs greater than that of the Sun.
According to the text,
Diameter of shadow = mins. = mins.
Where ϕ is the Moon's bhuja.
Rationale-From value of Āryabhaṭa-1,
Length of Earth's shadow =
= = yojanas,
Similarly, diameter of shadow =
= = = 798.6 or 800 yojanas approx.
= mins, for 10 yojanas = 1 min.
= mins
Mañjula takes 8300 in place of 7760. If, however, we take 855 yojanas as the linear measure of the diameter of shadow, we shall get
Diameter of shadow = mins. approx.
The commentator Sūryadeva Yajvā thinks that Mañjula has taken 850 ½ yojanas as the linear measure of the diameter of shadow.

भौमादीनां बिम्बमानानयनम्

अङ्गानीशा (६, ११) नखास्सूर्या (२०, १२) द्वियामा (२,२) दशताडितः ।
स्वशीघ्रच्छेददिग् (१०) योगहृता बिम्बानि भूसुतात्॥३५॥

Diameter of the Planets

The diameters (in terms of minutes) of the planets beginning with Mars are 6, 11, 20, 12, and 22, each multiplied by 10, and divided by the sum of the planet's own śīghra divisor.
That is, Diameter of Mars = mins. Diameter of Mercury = mins.
Diameter of Jupiter = mins. Diameter of Venus = mins.
Diameter of Saturn = mins.
Where D = śīghra divisor of that planet (given in chapter 3-verses 5-6). These rules are empirical.
The commentator Sūryadeva Yajvā has calculated the values of the true diameters of the Planets according to the methods given by Āryabhaṭa-1 and Mañjula for three positions, viz. (1) when the planets are at their śīghrocchas, (2) when they are at their mean distances, and (3) when they are at their śīghranīchas. Results are given below-

		True diameter according to Āryabhaṭa-1	True diameter according to Mañjula
Mars	(1)	0'46"	1'58"
	(2)	1'17"	2'36"
	(3)	3'48"	4'00"
Mercury	(1)	1'32"	2'49"
	(2)	2'8"	3'33"
	(3)	3'29"	4'49"
Jupiter	(1)	2'39"	3'22"
	(2)	3'12"	3'54"
	(3)	4'00"	4'39"
Venus	(1)	3'40"	4'7"

	(2) 6’24”	5’43”
	(3) 8’22”	9’19”
Saturn	(1) 1’27”	2’17”
	(2) 1’36”	2’29”
	(3) 1’48”	2’45”

These values are far remote from real values in modern astronomy-
Mars 14”.3, Mercury 9”, Jupiter 41”, Venus 39”, Saturn 17” (mean values)
Reason of higher values by A.K. upadhyay-(1) It is assumed thet the error is due to assumption that all planets have equal linear motion-hence their distance was calculated in ratio of orbital periods. However, sizes of śīghra orbits of planets indicate that original measures of orbit were correct but later astronomers misunderstood it.
(2) Actually, Sūrya-siddhānta has used 2 types of yojana-for earth and moon. We assume only one yojana measure which is wrong as Bhāskara-2 has used yojana = 8 kms. in Siddhānta-śiromaṇi (1600 parts of earth diameter) for astronomical use and 32 km yojana (32000 hands) in Līlāvatī for survey purpose. Similarly, we should calculate yojana for sun and star planets from present measures in kms. That comes to about 216 kms. which is 27 times the yojana used for earth-moon (= 8 kms). Bha = nakṣatra and number 27 also, so this can be called Bha-yojana = 27 x Bhū-yojana. Angular diameters of planets are much bigger as they are calculated for distance in 8kms. Calculating that in 27x8 kms unit, it will be approximately correct.
(3) D. Arka Somayāji thinks that higher measure of diameter is due to irradiance of planets due to which they appear bigger (his commentary on Siddhānta-śiromaṇi, Grahayuti adhikāra).
मन्दस्फुटास्वपातोनाद् ग्रहाच्छीघ्राज्ज्ञशुक्रयोः।
भुजाः षट्कृति (३६) सूर्याष्टि (१२,१६) नवाष्ट्यष्टि (९,१६,१६) हृताः क्रमात्॥३६॥
चन्द्राद् विक्षेपलिप्तास्स्युस्ताः कुजाद्यासताडितः। शीघ्रच्छेदहृतास्स्पष्टास्स्वर्णाख्या दक्षिणोत्तराः॥३७॥
Latitudes of Moon etc.
Substract the longitude of the planet’s ascending node from the true-mean longitude of the planet (in case of Mars, Jupiter, and Saturn) and from the longitude of the planet’s Śīghroccha (as reversely corrected for the mandaphala) in the case of Mercury and Venus. Reduce (the resulting difference) to bhuja and find the Rsine (bhujajyā) thereof, and multiply the Rsine (for Moon etc.) by 36, 12, 16, 9, 16, and 16 respectively. The results are the minutes of the latitudes for Moon etc. Those for Mars etc, mulyiplied by their own (corrected) vyāsas and divided by the corresponding śīghra divisors are their true latitudes. They are south or north according as the bhujas (from which they have been obtained) are positive or negative.
Thus formulae for celestial latitudes of planets are-
(1) Moon’s latitude =$8^0 8'$ (Moon – A) X 36
(2) Mars’ latitude =
(3) Jupiter’s latitude =
(4) Saturn’s latitude =
(5) Mercury’s latitude =

(6) Venus' latitude =
Where V = planet's corrected vyāsa,
D = planet's śīghra divisor
A = planet's ascending node,
And S' = planet's śīghroccha as reversely corrected for its mandaphala (equation of the centre)
The true-mean longitude in the case of Mars, Jupiter, and Saturn gives the heliocentric longitude of the planet; and S' – A, in the case of Mercury and Venus, given the longitudinal distance of theplanet from the ascending node. Hence the rule.
The values of the greatest celestial latitudes of the planets assumed in the above mentioned formulae are evidently as follows:

Planet	Greatest celestial latitude
Moon	8'8" X 36 = 292' 48"
Mars	8'8" X 12 = 97' 36"
Mercury	8'8" X 16 = 130'8"
Jupiter	8'8" X 9 = 73'12"
Venus	8'8" X 16 = 130'8"
Saturn	8'8" X 16 = 130'8"

Values by Āryabhaṭa-1 and Brahmagupta are-

Planet	Greatest celestial latitude according to	
	Āryabhaṭa-1	Brahmagupta
Moon	270'	270'
Mars	90'	110'
Mercury	120'	152'
Jupiter	60'	76'
Venus	120'	136'
Saturn	120'	130'

It will be noted that the values given by Mañjula are greater than those given by Āryabhaṭa-1 by about 8.5% in the case of Moon, Mars, Mercury, Venus and Saturn, but by 22% in the case of Jupiter.
The commentator Sūryadeva Yajvā says that the values of the greatest celestial latitudes of the Moon etc. being different in different works, Mañjula has himself determined his values by actual observation by the instruments Yaṣṭi etc.
युक्तिकालिकबिम्बान्तरं भेदयुद्धसम्प्राप्तिश्च
विक्षेपयोस्समदिशोरन्तरं भिन्नयोर्युतिः। बिम्बान्तरं लघुन्यस्मिन् भेदो मानार्धयोगतः॥३८॥
Distance between two planets in longitudinal Conjunction and criterion for Planetary Occulation (Bheda)-Take the difference or sum of the latitudes of te two planets (in longitudinal conjunction) according as thy are of like or unlike directions: then is obtained the distance between (the centres of) their discs. When the distance is less than half the sum of their diameters, there is conjunction (bheda) (of the upper planet by the lower one).
The amount by which the distance between the centres of the discs of the two planets is less than half the sum of their diameters is called the amount of occultation (Chhana). See Rājmṛgānka, (8/13).
The commentator Praśastidhara interpolates here the following verse-

सौम्यक्षेपोऽधिको जेता हीनक्षेपश्च दक्षिणे। उभयोरेकमार्गश्चेद् भिन्नमार्गे जयोत्तरः॥
= When two planets are of north latitude, the one with larger latitude is the victor, when of south latitude, the one with smaller latitude is the victor. This is so when their paths (diurnal circles) are in the same Gola; when in different, the northern one is the victor.
The Sūrya-siddhānta (7/23) adds-Venus is generally the victor, whether it lies to the north or to the south (of the other with which it is in encounter).
Puliśāchārya (Khaṇḍa-khādyaka, chapter 8-opening lines of Bhaṭṭotpala's commentary) combines the two statements-"(in case of an encounter) the planet that lies to the north of the other is the victor; but Venus is the victor (even) when it is to the south of the other."
भेदयुद्ध सूर्यग्रहणे च लम्बनानयनम्
ग्रहोनलग्नमक्ष (५)घ्नं लम्बनद्युगतं युतौ। लम्बनं द्व्यक्षकर्णाप्तं नतोनाहतविंशतेः॥३९॥
Lambana or Parallax in Longitude
In case of yuti (occultation or eclipse), multiply the lagna minus the (eclipsed) planet (in terms of signs) by 5: the result is the lambanadyugata (i.e. the day elapsed in terms of ghaṭīs etc to be used in computation of lambana). Calculate the hour angle (by substracting it from half the duration of the planet's day or vice versa). Diminish 20 by the hour angle (in trems of ghaṭī etc), then multiply by the hour angle, and divide by twice the palakarṇa (hypotenuse of the equinoctical midday shadow) (in terms of angulas and vyangulas); the result is the lambana (in terms of ghaṭīs).
That is, lambana = ghaṭīs, h being the hour angle (in terms of ghaṭīs).
Explanation-Let (lagna – planet) = x signs, say.
This is grahonalagna. The corresponding time of rising = ghaṭīs = 5x ghaṭīs.
This is grahonalagnamakṣaghnam and denotes lambanadyugata.
The corresponding hour angle
= half the duration of the planet's day – 5x ghaṭīs = h ghaṭīs, say.
Then according to the rule, lambana = ghaṭīs.
This formula is empirical.
Rationale by Sūryadeva Yajvā-
Case 1-When θ = 0. Sūryadeva Yajvā has shown that maximum value of lambana in this case = 48'30" or roughly 50', when h = 10 ghaṭīs. At that time, (20 – h) h = 100.
So, applying the proportion-When (20 – h) h = 100, the lambana amounts to 50', what will it be when (20 – h) h has lower value? The result is
Lambana = mins. = mins. = ghaṭīs.
(because 12 lambanakalās = 1 ghaṭī) = ghaṭīs.
Because when θ = 0, palakarṇa = 12.
Case 2-When = 0. In this case the equator is inclined to the horizon at an angle equal to (90 -) degrees. So, in this case
Lambana = = ghaṭīs.
It is noteworthy that Lalla befor Mañjula has given the same value of lambana, for Sūryadeva Yajvā has ascribed the following half verse to Lalla:
नतोननिघ्ना खयमा विभक्ता द्विघ्नाक्षकर्णेन विलम्बनाड्याः।
Lambana in nāḍīs =
Observation-The above rule is only approximate. For, at the equator when the Sun is

at the central ecliptic point (vtribha lagna), it correctly yields lambana = 0, but when the Sun is on the horizon, it gives lambana = 3 ½ ghaṭīs, the correct value being 4 ghaṭīs in this case.

Commentary by Praśastidhara adds 2 lines between first ang 4th part of this verse as a link-

ग्रहोनलग्नमक्ष (५)घ्नं लम्बनद्युगतं युतौ। (भागादि द्विगुणं कार्यं लम्बनद्युगतं भवेत्॥
लम्बनद्युगतात् पञ्चदशभिर्नतसाधनम्।) लम्बनं द्व्यक्षकर्णाप्तं नतोनाहतविंशतेः॥३९॥

Whole text is thus-In case of yuti, (occultation or eclipse), substract the longitude of the (eclipsed) planet (for the time of conjunction etc.) from the longitude of the lagna (for that time), and multiply that by 5. The resulting signs are the nāḍīs of the lambanadyugata. [Multiply the degrees etc. by 2: the result is the vināḍīs etc. of the lambanadyugata. From the lambanadyugata in terms of nāḍīs and vināḍīs, thus obtained, calculate the nata (i.e hour angle) by substracting it from 15 ghaṭīs]. Twenty diminished and then multiplied by that nata, and the result (obtained) divided by twice the akṣakarṇa (or palakarṇ) gives the lambana (in terms of nāḍīs).

Note-15 ghaṭīs are prescribed here in place of half the duration of the planet's day (prescribed in the previous rule). The commentator Parameśvara says-"one should always take here 15 ghaṭīs here in place of half the duration of the planet's day" He furher says: "Those who have explained the term dinārdha as meaning 'half the duration of the planet's day, calculated with help of chara or twice the ascensional difference are wrong, because there is lambana at the dṛkṣepalagna also."

Regarding the rule for finding the lambana, stated above, Yallaya remarks: "The lambana calculated with great effort from the rules stated in the Siddhāntas being different by one or two vighaṭikās from its actual value and the lambana computed from the rules stated in the (Laghu) mānasa being in agreement with the actual value, all astronomers compute the planets according to the rule stated in the (Laghu) mānasa."

खार्कानयनम्

प्राक्पश्चाल्लम्बनेनोनयुक्तं दिनगतं स्फुटम्। तन्नताक्षां (५)शहीनः प्राक् सूर्यः खार्कोऽन्यथा युतः॥४०॥

Khārka or Madhyalagna

Diminish or increase the day elapsed, by the lambana, according as it is the eastern or western half of the celestial sphere: the result is the true value of the day elapsed. In the eastern hemisphere, substract (signs equal to) one fifth of the (corresponding) nata-ghaṭīs from the longitude of the Sun; in the contrary case (i.e. in western hemisphere), add the same: the result is the longitude of the Khārka (i.e, the madhyalagna or the meridian ecliptic point).

It is assumed that one-fifth of a sign rises on the equatorial horizon in 1 ghaṭī.

Khārka, according to the commentator Sūryadeva Yajvā, means the central ecliptic point (vitribha or tribhonalagna). But this is approximately taken to be so.

Parameśvara says: "This is what has been said: When the day elapsed at the time of conjunction of the Sun and Moon (lambanadyugata) is less than 15 ghaṭīs constituting the day length, substract the lambanaghaṭīs from the day elapsed at the time of conjunction of the Sun and Moon; when the day elapsed at the time of conjunction of the Sun and Moon is greater than 15 ghaṭīs constituting the day-length, add the lambanaghaṭīs from the day elapsed at the time of conjunction of the

Sun and Moon; the result is the time of the middle of the eclipse.

From the day elapsed thus corrected for the lambana and the day-length obtained by the application of the chara, obtain the nataghaṭīs. Dividing these nataghaṭīs by 5, take the quotient as degrees. Then, multiplying the remainder of that by 60 and dividing by 5, take the quotient as minutes. Substract these signs etc. from or add them to the longitude of the Sun for that time, according as the day elapsed corrected for the lambana is less or greater than half the day-length. The longitude of the Sun thus corrected gives the longitude of the so called Khārka."

नतानयनम्

तदिष्टचरषड् (६)घातपलभाप्तेन संस्कृतात्। पलभोनाहतात् खाक्षाद् (५०) द्वि(२)घ्नात्तत्त्वै(२५)र्हृता नतिः॥४१॥ Nati or Parallax in Latitude

Find the product of the chara (vināḍīs) (obtained from the tropical longitude of that Khārka) and 6 and divide by the palabhā, and apply it to 50 diminished and multiplied by the palabhā (as a substractive or additive correction, according as the Sun is in the six signs beginning with Aries or in the six signs beginning with Libra). Then, multiply that by 2 and divide by 25: the result is the nati (in terms of minutes).

That is, Nati = mins.

+ or – sign being taken according as the Sun is in the six signs beginning with Libra or in the six signd beginning with Libra.

Rationale-this rule is based on 2 lemmas-

Lemma 1-The latitude degrees

The commentator Sūryadeva Yajvā says: "Here, it is assumed that the latitude degrees

Parameśvara too, in his Grahaṇāṣṭaka (verse 3), states the same formula. The formula, however, is empirical and approximate.

Verification-

When palabhā = 0, , which is true at the equator..

When palabhā = 5 angulas, 22^0 30', which is approximately true at Ujjain. It may be mentioned that, according to Āryabhaṭa-1, the latitude at Ujjain = 22^0 30'.

Lemma 2-the declination mins.

Sūryadeva Yajvā says that charavināḍīs =

Example-We have charavināḍīs = approx.

= = approx., being in terms of minutes.

Therefore, mins. (approx.)

Using these two lemmas, Mañjula's rule may be derived as follows-

Nati = 48'30" sin (= 48'.5 approx.

= 48'.5 = 48'.5

Where being in minutes, R is also in minutes equal to 3438'.

= ,

Because 6/R = 6/3438 = 1/573

= .

In corroboration of the rule of the text, Sūryadeva Yajvā cites the following verse of some anonymous writer

तन्मध्यलग्नोत्थचराद्रसघ्नात् पलप्रभाप्तेन च संस्कृतच्च। पलप्रभोनाहतपूर्णबाणाद् द्विघ्नात्तथा

तत्त्वहृतान्नतिः स्यात्॥
Which too, states the same rule.
Since the palabhā is always of south direction, the nati too is always of south direction, says the author of Rāja-mṛgānka (7/13).
स्पष्टविक्षेपानयनं छाद्यछादकग्रहपरिज्ञानञ्च
तात्कालिकेन्दुविक्षेपो युक्तो नत्यैकदिक्कया। हीनोऽन्यथा युतौ स्पष्टश्छादकोऽधःस्थितो ग्रहः॥४२॥
Nati Correction
The instantaneous latitude of the eclipsed planet (indu) should be increased by the nati, provided they are of like directions; or diminished, in the contrary case. In case of eclipse or occultation, the lower planet is evidently the eclipser (of the upper one). When the latitude is increased or diminished by the nati, the result is the true latitude, i.e the latitude corrected for parallax in latitude.
मध्यस्थित्यर्धानयनम्
बिम्बान्तरकृतिं प्रोज्झ्या मानैक्यार्धकृतेः पदम्। षष्टिघ्नं समदिग्गत्योरन्तराप्तं स्थितेर्दलम्॥४३॥
Sthityardga or Semi-Durations
Substact the square of the (shortest) distance between (the centres of) the discs (of the eclipsed and eclipsing bodies) from the square of half the sum of the diameters (of those bodies) and then take the square-root. Multiply that by 60 and divide by the motion-difference of the two bodies, if they are moving in like directions: the result is the sthityardha (in terms of ghaṭīs)
Note- Rāja-mṛgānka (7/24) adds: “When of the two planets, one is in retrograde motion and the other in direct motion, then the sthityardha is obtained by dividing by the sum of their daily motions.”
स्पर्शमोक्षस्थित्यर्धानयनम्
स्थित्यर्धे चन्द्रविक्षेपकृतेन्द्रां(१४४)शयुतोनिते। स्पष्टे स्पार्शिकमूनं स्याद्युगविक्षेपेऽन्यथा महत्॥४४॥
On increasing and diminishing the sthityardha (severally) by 1/144 of the Moon’s latitude are obtained the true sthityardhas, the smaller one being the spārśika provided the Moon is in even nodal quadrant; otherwise the larger one is spārśika.
The above rule is meant to find the spārśika and maukṣika sthityardhas without using the process of iteration (asakṛtakarma).
In the figure below, let BC be the ecliptic and XY the Moon’s orbit (relative to the Shadow at S). M and S are the centres of the Moon and the Shadow at the time of their geocentric conjunction. M_1 is the position of the Moon’s centre at the beginning of a lunar eclipse. M_1S = sum of the semi-diameters of the Moon and Shadow; M_3S = sum of the semi-diameters of the Moon and Shadow, M_2 is position of the Moon’s centre at the middle of the eclipse, $M_1M_2 = M_2M_3$.

From the triangles SM_2M_1 and SM_2M_3, both right-angled at M_2, we have
$M_1M_2 = M_2M_3 =$ or
= (sum of semidiameters of Moon and shadow)^2 – (shortest distance between them)^2
or, sthityardha = M_1M_2 mins. = ghaṭīs.
Now in the triangle SM_2M_1, right-angled at M_2, MS is the Moon’s latitude for the time of conjunction of M and S and angle MSM_1 = i, the inclination of the Moon’s orbit to the ecliptic.
Therefore, M_2M = = , because according to Mañjula, i = 292’

=   ghaṭīs = ghaṭīs
Therefore, spārśika sthityardha = M_1M_2 + M_2M = sthityardhaghaṭīs + MS/144 ghaṭīs
And maukṣika sthityardha = M_2M_3 + M_2M = sthityardhaghaṭīs - MS/144 ghaṭīs
When the conjunction of the Moon and the shadow occurs in an even quadrant, MS/144 ghaṭīs are added and substracted reversely.

अर्कग्रहणे स्पर्शमोक्षकालसाधनम्

तदूनयुतमासान्तद्युगते कृतलम्बने। स्पर्शो मोक्षो भवेद् भानो लग्नादिन्दुपूर्वाणि॥४५॥

Time of Contact and Separation in a Solar Eclipse

(Severally) decrease and increase the māsāntadyugata (i.e. the day elapsed sine sunrise at the end of the lunar month when the Sun and Moon are in conjunction), corrected for lambana, by the (spāsśika and maukṣika) sthityardhas: the results are the times of contact and separation in the case of a solar eclipse. In case of a lunar eclipse, correction for lambana and nati are not applied.

अक्षवलनानयनम्

युतिमध्यनताभ्यस्ता पलभा भानु(१२)भाजिता। प्रागुदग्दक्षिणं पश्चाद्वलनं रविमण्डले॥४६॥

Akṣavalana

Multiply the palabhā by the nata (i.e. hour angle), in ghaṭīs, for the time of the middle of the eclipse (yutimadhya) and divide by 12: the result is the akṣavalana in terms of angulas for a circle of diameter of 32 angulas. Its direction is north in the eastern hemisphere and south in the western hemisphere.
The akṣavalana is the deflection of the east point of the equator from the east point of the prime vertical, on the horizon of the eclipsed body.
The above rule says that, in a circlre of radius 16 angulas,
akṣavalana = angulas,
which is north in the eastern hemisphere and south in the western hemisphere.
Rationale - Applying the proportion: “When the nataghaṭikās are equal to 15, the akṣavalana is equal to the local latitude ϕ^0, what will be the value of the akṣavalana corresponding to the given nataghaṭikās?” The result is
akṣavalana =   degrees =   minutes
Now palabhā =   approx.
Therefore, akṣavalana =   minutes
In a circle of radius 3438’.
=   angulas =   angulas
In a circle of radius 16 angulas. Hence the rule.
When the eclipsed body is in the eastern hemisphere, the direction of the akṣavalana is north (as measured from the east point of the horizon of the eclipsed body); and when the eclipsed body is in the western hemisphere, the direction of the akṣavalana is south (as measured from the west point of the horizon of the eclipsed body).

अयनवलन-पारमार्थिकवलनयोरानयनम्

ग्रहेणायनयोरल्पमन्तरं द्विघ्नमायनम्। वलनं स्यात्तयोर्योगविश्लेषात् पारमार्थिकम्॥४७॥

Ayanavalana and True Valana

The distance, in terms of signs etc. of the nearer solstice from the planet, multiplied by 2, gives the ayanavalana (in terms of angulas). The true valana is the sum or difference of the two (valanas, ākṣa and āyana), (according as they are of like or

unlike directions).
The ayanavalana is the deflection of the east point of the ecliptic from the east point of the equator on the horizon of the eclipsed body.
According to the rule stated above, ayanavalana = 2d angulas,
Where d is the distance of the nearer solstice from the eclipsed planet.
Rationale-Suppose that the eclipsed planet is at first point of Aries, i.e, at the distance of 3 signs from the nearer solstice. Then we know that in the circle centred at the eclipsed planet and radius equal to 3438 minutes.
Rsin (ayanavalana) = Rsin 24^0 or 1397 mins.
Therefore in the circle centred at the eclipsed planet and radius equal to 16 angulas,
Rsin (ayanavalana) = = 6 angulas.
It means that when the distance of the nearer solstice from the eclipsed planet is 3 signs, Rsin (ayanavalana) or roughly the ayanavalana is equal to 6 angulas, so that when the distance of the nearer solstice from the eclipsed planet is d signs, the ayanavalana is equal to 2d angulas. Hence the rule.
Direction of the ayanavalana- When he eclipsed body is in the northern hemisphere, then towards the east of the eclipsed body the direction of the ayanavalana is north and towards the west of the eclipsed body the direction of the ayanavalana is south.
When the eclipsed body is in the southern hemisphere, the direction of ayanavalana is just the reverse.
The true value is the deflection of the east point of the ecliptiv from the east point of the prime vertical on the horizon of the eclipsed body.
अंगुल-मानः- षडक्षां (५६)गुलयस्त्यग्रे दृङ्मध्यादंशकोङ्गुलम्।
Angula-degree Relation
At the end of the Yaṣṭi (radius) of 56 angulas from the centre of the directions (diṅmadhya), one angula is equal to one degree.
The value of a radian has been assumed here as equal to 56^0. The correct value is $57^017'45''$.
What is meant by the above rule is that if a circle is drawn with radius equal to 56 angulas, the circumference will contain 360 angulas approx. Then 1^0 of the circumference of circle will be equal to 1 angula.
The rule is intended to be used for finding the number of degrees between two planets in conjunction in longitude. Parameśvara says: “Having constructed a Yaṣṭi measuring 56 angulas in length, attach at its end, at right angles to it, a scale graduated with the marks of angulas. Keeping (the other end of) the Yaṣṭi between the eyes, observe the two planets in such a way that they lie along the vertical scale. Then as many angulas are there between the planets, so many degrees lie between them.”
परिलेखविधिः- Parilekha or Diagram of Eclipse
दिग्वृत्तपरिधौ प्राची वलनाग्रे ततोऽपरा॥४८॥
On the circumference of the circle of the directions there is a Prāchī (east-west line). At the end of the valana there is another (east-west line) which is different from that.
तत्पूर्वापररेखातो विक्षेपान्तरिता परा। रेखा मन्दगतेर्मार्गस्तद्वच्छीघ्रगतेरपि॥४९॥
From that (later) east-west line, at the end of the (lower planet’s) latitude, draw a line parallel to it. This is the path or locus of the slower planet. In the same way draw the

path or locus of the faster planet.
What is meant is this: “Construct a circle of radius 16 angulas, and mark the east, west, north, and south cardinal points on its circumference. This circle is called the circle of cardinal directions (Digvṛtta). From the east point of this circle lay off the valana in its own direction, and put there a point. This point is called the east point at the end of the valana (valanāgraprāchī). Treating this point as the east point, draw the east-west and north-south lines. These lines are called the direction lines at the end of the valana (valanāgra-diksūtra).
“Now draw a line parallel to this east-west line at the distance of the slower planet’s latitude. This is the path of the slower or eclipsed planet. Similarly, draw another line parallel to the same east-west line at the distance of the faster planet’s latitude. This is the path of the faster or eclipsing planet. This is in the case of an eclipse of a planet by another.”
In case of lunar eclipse, the slower planet (viz. the shadow) is the eclipsing body and the faster planet (viz. the Moon) is the eclipsed body. In the case of a solar eclipse, the slower planet (viz. the Sun) is the eclipsed and the faster planet (viz. the Moon) is the eclipsing body.”
“Since the Sun and the shadow move on the ecliptic and have no latitude, therefore the path of the eclipsed planet (viz. the Sun) in the case of a solar eclipse), as well as the path of the eclipseing planet (viz. the shadow) in the case of a lunar eclipse is the same as the east-west line at the end of the valana. Thus, in both the cases the line drawn at the distance of the latitude is the Moon’s path”
वृत्तमध्याद्यथायातविक्षेपाद् ग्रहमध्ययोः। ग्रहयोर्युतिमध्यं स्यात् ततोऽन्यत्र ग्रहान्तरात्॥५०॥
From the centre (along the north-south line), lay off the latitudes of the two planets for the middle of the eclipse, as obtained, (towards the north or south as the case may be). Where these meet the paths of the planets, there lie the planets for the time of the middle of the eclipse. At any other time, draw the Parilekhas (i.e exhibit the iṣṭagrāsa) by making use of the distance between the two planets.
What is meant here has been explained by the commentator Parameśvara as follows-
“Taking the point of intersection of (1) the north-south line at the end of valana and (2) the path of the Moon as centre, and the Moon’s semi-diameter, in terms of angula, as radius, draw a circle (denoting the Moon’s disc). Next taking the centre of the circle of radius 16 angulas itself as centre, and the Sun’s semi-diameter, in terms of angulas, as radius, draw the Sun’s disc. Then whatever portion of the Sun’s disc is covered by the Moon’s disc is the invisible portion of the Sun (at the middle of the solar eclipse). In case of a lunar eclipse, draw the Shadow disc in place of the Sun’s disc.”
“At any other time, different from the middle of the eclipse, one should draw the Parilekha for that time, by making use of the motion-difference in minutes as reduced to angulas, the valana of that time, and the Moon’s latitude for that time”
The method for drawing the Parilekha for the middle of the eclipse as also for the desired time is the same as described in the other works of Hindu astronomy.
इति लघुमानसे ग्रहयुतिग्रहणद्वयपरिलेखनाधिकारः षष्ठः।
= Thus ends chapter 6 in Laghumānasa describing conjunction, eclipse and diagram.

अथ ग्रहोदयास्तमयाधिकारः सप्तमः

Chapter 7-Rising and Setting of Heavenly bodies

अक्षदृक्कर्माख्यसंस्कारः

तिथि (१५)घ्नाच्चरसंस्कारात् स्वोदयेनांशकादिकम्। स्वर्णं क्षेपवशात् कार्यं ग्रहे षड्भयुतेऽन्यथा॥५१॥

Akṣadṛkkarma or visibility correction due to local latitude-

Multiply the chara-correction (see verse 55 below) by 15 and divide by the vināḍīs of the oblique ascension of the sign occupied by the planet. The resulting degrees should be added to or substracted from the true longitude of the planet at its rising according as the planet's latitude is positive or negative (i.e. south or north). In the case of setting (the chara-correction is multiplied by 15 and divided by the vināḍīs of the oblique ascension of the seventh sign from the position of the true planet at sunrise and) the resulting vināḍīs are applied to the true longitude of the planet as increased by six signs in the contrary way (i.e. they are added when the planet's latitude is negative and substracted hwen the planet's latitude is positive).

That is, akṣadṛkkarma = degrees

Rationale-From verse 55 below, we have

Chara-correction = vināḍīs (1)

The present rule tells ushow to find the arc of the ecliptic which rises in half the vināḍīs given by (1). The proportion used for the purpose is: "If in the vināḍīs of the oblique ascension of the sign occupied by the planet (i.e. the rising sign) there rise 30 degrees of the ecliptic, how many degrees wiil rise during half the vināḍīs given by (1)?" The result is

degrees

= degrees

Hence the rule.

अयनदृक्कर्माख्यसंस्कारः

ग्रहस्योत्क्रमकोटिघ्नात् क्षेपाब्ध्यं(४)शात् स्वलग्नहृत्। क्षेपकोट्योस्समानत्वे स्वर्णं भागाद्यनुत्क्रमात्॥५२॥

Ayana-Dṛkkarma or Visibility Correction due to Planet's Ayana-

Multiply one-fourth of the planet's latitude by Rversed sine of the planet's koṭi and divide by the vināḍīs of the oblique ascension of the sign occupied by the planet at its rising. The resulting degrees should be added to or substracted from the true planet corrected for the first (i.e. akṣa) dṛkkarma, according as the planet's latitude and the planet's koṭi are of like or unlike denominations (In the case of setting, reversely).

That is, ayana dṛkkarma = degrees

Rationale-Let β denote the planet's latitude and V the vināḍīs of the oblique ascension of the sign. Then

ayana dṛkkarma = degrees

=

= , because $8^0 8'$ sin $24^0 = 3^0 15'$

= =

= degrees

When the akṣadṛkkarma and ayanadṛkkarma are applied to the planet's longitude at its rising, one gets the planet's udayalagna (i.e. the longitude of that point of the ecliptic that rises with the planet), and when they are applied to the planet's longitude at setting one gets the planet's astalagna (i.e. the longitude of that point of the ecliptic that sets with the planet).

ग्रहाणामस्तार्कानयनम्

सूर्याष्टिविश्वरुद्राष्टतिथ्यंश(१२,१६,१३,११,८,१५)घ्नैः खखाग्निभिः(३००)।
प्राग्भोदयाप्तैर्युक्तोनस्सूर्योऽस्तार्कश्शशाङ्कतः॥५३॥

Udayārka and Astārka for Moon etc.-

Multiply 300 severally by 12, 16, 13, 11, 8, and 15 (i.e. by the time degrees of heliacal visibility of Moon etc) and divide by the vināḍīs of the oblique ascension of the sign occupied by the planet. Severally add the resulting degrees to and substract them from the true longitude of the planet: the results are called the Udayārka and Astārka of the Moon etc.

The Udayārka of a planet is the position of Sun when the planet rises heliacally; and the Astārka of a planet is the position of Sun when the planet sets heliacally.

The above rule is based on the formula:

Degrees of the ecliptic that rise during the time-degrees for rising or setting of a planet

= ,

Where T = time-degrees in vināḍīs = time-degrees X10

And V = vināḍīs of the oblique ascension of the sign occupied by the planet.

अस्तगस्य ग्रहस्य लक्षणम् (वाराणसी प्रति)

विक्षेपो भिन्नतुल्यांशो वलनघ्नः खखाङ्क (९००)कैः।
हृतोंऽशास्तैर्युतोनस्सन् ग्रहोऽस्तार्कान्तरेऽस्तगः॥५३॥

Dṛkkarma or Visibility Correction (Alternative Method)-

The celestial latitude (of a planet), when multiplied by the valana (whether of different or same direction), and divided by 900 gives the degrees (of the visibility correction for the planet). If the planet after being increased or decreased by these degrees (as the case may be) lies between the Astārka and the Udayārka of the planet, it should be understood that the planet) is in helacal setting.

That is, visibility correction = degrees,

Where β is the celestial latitude of the planet (in minutes of arc) and v the planet's valana (in angulas).

Rationale-In the figure below, let AP be the local horizon and AB the ecliptic; P the planet and PB the planet's celestial latitude β. Then the angle APB is the planet's valana and angle APB is very small, treating the spherical triangle ABP,right-angled at β, as a plane triangle, we have

arc AB = β tan (angle APB)

= mins. approx., R = radian in minutes

= degrees = degrees,

Because, valana in angulas corresponds to a circle of radius 16 angulas.

= degrees = degrees approx.

Note-the above visibility correction is added to or substracted from the longitude of the planet according as the celestial latitude and the valana are of unlike or like directions.

अगस्त्यस्योदयास्तज्ञानम्

अगस्त्यस्यास्तोदयार्कांशास्सप्तशैला (७७)स्स्वराङ्ककाः (९७)।
अष्ट (८) घ्नविषुवच्छाया हीनयुक्तास्स्वदेशजाः॥५४॥

Astārka and Udayārka for Canopus (Agastya)-

The degrees of Astārka and Udayārka for the star Canopus (Agastya) are 77 and 97, respectively diminished and increased by 8 times the equinoctical midday shadow at the local place.

That is, Udayārka for Canopus = 97 + 8P degrees

And Astārka for Canopus = 77 - 8P degrees,

where P denotes the equinoctical midday shadow, in terms of angulas.

Rationale-In case of Canopus,

Udayārka = Polar longitude for Canopus + akṣadṛkkarma for Canopus
+ time degrees for heliacal rising or setting of Canoups,

and Astārka = Polar longitude for Canopus - akṣadṛkkarma for Canopus
- time degrees for heliacal rising or setting of Canoups

The commentator Sūryadeva Yajvā has shown that

Polar longitude for Canopus = 87^0

akṣadṛkkarma for Canopus = 8P approx.

and time degrees for heliacal rising or setting of Canoups = 10^0.

Gence the rule.

स्फुटचरसंस्कारः

चरतानां(४९)श षड्वर्ग(३६)विश्लेषेणाक्षभाहतात्। स्वविक्षेपादवाप्तेन स्वचरं संस्कृतं स्फुटम्॥५५॥

Chara Correction-

By the difference between 49th part of the planet's chara and 36, divide the planet's own latitude as multiplied by the equinoctical midday shadow (akṣabhā or plabhā): apply what is obtained to the planet's own chara. Then is obtained the true chara.

That is, true chara = chara ,

Where chara stands as usual for twice the planet's ascensional difference in terms of vinādḍīs, + or – sign being taken according as

Chara and chara correction

or planet's bhuja and planet's latitude

are of like or unlike signs. (North latitude should be taken as + and south as -)

Rationale-In the figure below, which represents the celestial sphere for a place in latitude ϕ, SEN is the horizon, and Z the zenith; RET is the equator and P its north pole. AYB is the ecliptic. X is a planet at the rime of its rising on the horizon. PXC is the planet's hour circle (dhruvaprotavṛtta) and Y the point where it intersects the ecliptic. rDYt is the diurnal circle through Y, and D the point where it intersects the horizon. PDF is the hour circle through D.

In the triangle XDY, angle XDY = 900 – ϕ, and arc XY = planet's latitude β (approx.), so that arc DY = β tan ϕ.

Now mean chara = 2EF approx. and true chara = 2EC.

Therefore, chara correction = 2EC – 2EF = 2FC.

Now DY = XY tan ϕ = β tan ϕ = .

∴ 2FC = 2 . = asus or mins.

= vināḍīs = vināḍīs
This is the correct formula for the chara correction as shown by the commentator Sūryadeva Yajvā. Mañjula has replaced the denominator 36. Rcos by 36 (planet's chara)/49 empiriclly.
The rationale given by N. K Mazumdar is incorrect.
इति लघुमानसे ग्रहोदयास्तमयाधिकारः सप्तमः।
Thus ends chapter 7 in Laghumānasa about rsising and seting of planets.
अथ महापाताधिकारः अष्टमः (Chapter 8-Mahāpāta)
पातस्थितिकालपरिज्ञानम्
अन्तरेऽर्केन्दुदिनयोर्विनाड्यः पलभाल्पिकाः।यावत्तावद् व्यतीपातो वैधृतस्तद्दिवानिशोः॥५६॥
Duration of Vyatīpāta and Vaidhṛta
The phenomenon of Vyatīpāta continues until the vināḍīs of the difference between the Sun's day-length and the Moon's day-length are less than (the angulas of) the equinctical midday shadow (palabhā). The phenomenon of Vaidhṛta continues until the vināḍīs of the difference between the Sun's day-length and the Moon's night-length (or the Sun's night-length and the Moon's day-length) are less than (the angulas of) the equinctical midday shadow.
The phenomenon of Vyatīpāta (also called Chakrārdha Vyatīpāta or Lāṭa Vyatīpāta) is said to occur when the Sun and Moon are in the same Gola (hemisphere, northernor southern) but in different ayanas and the sum of their longitudes is equal to 6 signs or 180 degrees. If the Moon has no celestial latitude, the declinations of the Sun and Moon are equal; otherwise the declinations of the Sun and Moon are equal sometime earlier or later. The time when the declinations of the Sun and Moon happen to be same is called the middle of Vyatīpāta. Sometime prior to this the difference between the declinations of the Sun and Moon happen to be equal to the sum of semi-diameters of the Sun and Moon: Vyatīpāta is then said to begin. Sometime later than this the difference between the declinations of the Sun and Moon happen to be equal to the sum of semi-diameters of the Sun and Moon: Vyatīpāta is then said to end.

The phenomenon of Vaidhṛta (also called Vaidhṛta Vyatīpāta) is said to occur when the Sun and Moon are in the same Ayana but in different Gola (hemisphere, northern or southern) and the sum of their longitudes is equal to 12 signs or 360 degrees. If the Moon has no celestial latitude, the declinations of the Sun and Moon are then equal in magnitude but opposite in sign; otherwise the declinations of the Sun and Moon are numerically equal sometime earlier or later. The time when the declinations of the Sun and Moon are numerically same is called the middle of Vaidhṛta. Sometime prior to this the difference between the numerical value of their declinations happen to be equal to the sum of their semi-diameters: Vaidhṛta is then said to begin. Sometime later than that the difference between the the numerical value of their declinations again happens to be equal to the sum of their semi-diameters: Vaidhṛta is then said to end.
The rule stated in the text gives the durations of Vyatīpāta and Vaidhṛta.
Derivation-In case of Vyatīpāta, the Sun and Moon being in the same Gola,
Sun's day-length = 30 nāḍīs Sun's charavināḍīs
And Moon's day-length = 30 nāḍīs Moon's charavināḍīs.

Therefore,
Sun’s day-length Moon’s day-length = Sun’s charavināḍīs Moon’s charavināḍīs   (1)
At the time of middle of Vyatīpāta, Sun’s declination = Moon’s declination,
So that, Sun’s charavināḍīs = Moon’s charavināḍīs.
Therefore, from (1), at the time of middle of Vyatīpāta,
Sun’s declination - Moon’s declination
= Sun’s semi-diameter + Moon’s semi-diameter = 32” approx.
The corresponding difference between the Sun’s and Moon’s charavināḍīs
= 2 32 tan ϕ X 1/6 (roughly)
= 2 32   = palabhā (in angulas), approx.
Therefore, at the beginning or end of Vyatīpāta,
Sun’s day-length (in vināḍīs) Moon’s day-length (in vināḍīs) < palabhā (in angulas).
Hence it follws that Vyatīpāta continues until
Sun’s day-length Moon’s day-length (in vināḍīs) < palabhā (in angulas).
In case of Vaidhṛta, the Sun and Moon being in different Gola,
Sun’s day-length (night-length) = 30 nāḍīs Sun’s charavināḍīs
And Moon’s night-length (day-length) = 30 nāḍīs Moon’s charavināḍīs.
Therefore, Sun’s day-length (night-length) Moon’s night-length (day-length)
= Sun’s charavināḍīs Moon’s charavināḍīs.
Hence, proceeding as in the case of Vyatīpāta, we find that Vaidhṛta continues until Sun’s day-length (night-length) Moon’s night-length (day-length) < palabhā (in angulas).
इति लघुमानसे महापाताधिकारः अष्टमः Thus ends chapter 8 about Mahāpāta in Laghumānasa.

अथ चन्द्रशृङ्गोन्नत्याधिकारो नवमः (Chapter IX-Elevation of Moon’s Horns)

चन्द्रच्छायानयनम्

विहितोदयदृक्कर्म तत्कालेन्दुविलग्नतः। शशाङ्कद्युगतं तस्मात् तद्दिनाच्चार्कवत्प्रभा॥५७॥

Moon’s Shadow

From the instantaneous longitude of the Moon corrected for the two visibility corrections (akṣa-dṛkkarma and ayana-dṛkkarma) for rising and the longitude of the rising point of the ecliptic (vilagna). Find the day elapsed of the Moon, and then from that and from the length of Moon’s day deduce the gnomonic shadow due to moon-light, as in the case of the Sun.
The successive steps of the procedure are:
(1) First find the elapsed portion of the Moon’s day by the formula:
Elapsed portion of the Moon’s day
= oblique ascension of the untraversed part of the sign occupied by the visible Moon (i.e. instantaneous Moon corrected for the visibility corrections) + oblique ascension of the traversed part of the sign occupied by the rising point of the ecliptic + oblique ascension of the intervening signs.
(2) Then find the Moon’s true charas by using the rule stated in verse 55.
(3) By using the Moon’s true chara, find the length of the Moon’s day.
(4) Using that, find the Moon’s meridian shadow in the manner described in verse 26.
(5) Finally, find the Moon’s natakāla (hour angle) by the formula:

Moon's natakāla = Moon's half-day – elapsed portion of the Moon's day.
And using this Moon's natakāla, find the Moon's instantaneous shadow in the manner stated in verses 27-28.
The shadow due to a planet is also obtained similarly. Sita and Asita
सितासितमानानयनम्
द्व्यू (२)नाः पक्षादितिथ्यर्धास्सस्वागां (७)शस्सितासिते।
Sita and Asita
The number of karaṇas elapsed since the beginning of the (current) fortnight diminished by 2 and then (the difference obtained) increased by one-seventh of itself, gives the measure of the sita if the fortnight is light (or bright) or the asita if the fortnight is dark.
That is, in the light fortnight,
Sita = (K - 2) (1 + 1/7) angulas
Where K is the number of karaṇas elapsed since the beginning of the light fortnight; and in the dark fortnight,
Asita = (K - 2) (1 + 1/7) angulas
Where K is the number of karaṇas elapsed since the beginning of the dark fortnight.
The karaṇa is obtained as follows: Let S and M be the longitudes of the Sun and Moon in terms of degrees, then the quotient obtained by dividing M – S by 6 gives the number of karaṇas elapsed since the beginning of the light fortnight, and the quotient obtained by dividing M – (S + 180^0) by 6 gives the number of karaṇas elapsed since the beginning of dark fortnight.
In the light fortnight, the Moon is first visible when it is at a distance of 12 degrees from the Sun, i.e., when 2 karaṇas have just elapsed, so the proportion is made here with 180 – 12 = 168 degrees instead of 180 degrees. If M and S denote the longitudes of the Moon and the Sun in terms of degrees, the proportion implied is: "When (M – S – 12^0) amount to 168^0 the measure of the sita is 32 angulas, what will be the measure of the sita when (M – S – 12^0) has the given value?" The result is
Sita = angulas = angulas = (K – 2) (1 + 1/7) angulas,
Where K denotes the number of of karaṇas elapsed since the beginning of the light fortnight.
In the dark fortnight, the moon becomes completely invisible when the moon is 12 degrees behind the Sun, i.e., when 2 karaṇas are yet to elapse of the dark fortnight. So the proportion implied in this case is: "When M – (S + 180^0) – 12^0 amount to 168^0 the asita amounts to 32 angulas, what will be the measure of the sita when (M – (S + 180^0) – 12^0 has the given value?" The result is:
Asita = = (1 + 1/7) = (K – 2) (1 + 1/7) angulas,
Where K denotes the number of of karaṇas elapsed since the beginning of the dark fortnight. Hence the rule.
शृङ्गोन्नतिपरिलेखोपयोगिस्फुटवलनानयनम्
विक्षेपव्योमधृत्यं (१८०)शसंस्कृतं वलनं स्फुटम्॥५८॥
True Valana
The valana (obtained in verse 17) becomes true (and suitable for use in the case of elevation of the Moon's horns) when corrected by 1/180 of the Moon's latitude.
That is, true valana = valana ,

+ or – sign being taken in the light fortnight according as the valana and the Moon's latitude are of like or unlike directions, and in the dark fortnight according as the valana and the Moon's latitude are of unlike or like directions.

In the above formula, the valana and the true valana are for the circle of radius 16 angulas. Let β be the Moon's latitude. Then the Moon's latitude for the circle of radius16 angulas

= angulas = angulas. Hence, true valana = valana angulas.

Mañjula takes 180 in place of 215. Hence the rule.

The commentator Sūryadeva Yajvā has suggested thet the correct reading of the text should be:

विक्षेपतिथिदस्रां (२१५)शसंस्कृतं वलनं स्फुटम्॥

In the diagram exhibiting the diagram of the moon's horns, the rue value is the inclination of the line joining the Sun and Moon from the line joining the east and west cardinal points (which is supposed to be at right angles to the plane of the horizon).

शृङ्गोन्नतिपरिलोखोपयोगि-छेदानयनम् (वाराणसी प्रति)

पक्षादतीततिथ्यर्धतिथ्य(१५)न्तरहृतोऽधिकः। नृप(१६)वर्गोऽर्धितच्छेदं शुक्लान्ताद्विधुमण्डले॥५८॥

Chheda or Radius of inner arc of Sita

The difference of 15 and the numbers of karaṇas (tithyardhas) elapsed since the beginning of the (current) fortnight should be increased by 16^2 divided by the same difference, and the sum thus obtained should be halved: what is obtained is the Chheda. This should be laid off from the (inner) extremity of the sita (śukla) towards the interior of the Moon's circle.

That is, Chheda = ,

Where K is the numbers of karaṇas elapsed since the beginning of the current fortnight.

The Chheda defined here is generally known as parilekhasūtra and denotes the radius of the circle forming the inner boundary of the Moon's illuminated part.

Let ENWS (in the figure below) be the Moon, E, W, N, and S being the east, west, north, and south points on its circumference, WC is the sita, and NCS as arc of the circle forming the inner boundary of the Moon's illuminated part, O being its centre and ON, OC, or OS its radius, called chheda by our author.

Assuming the Moon's radius AN to be equal to 16 angulas, the sides of the right-angled triangle NAO, right angled at A, may be written as

NA = 16 angulas, OA = angulas, ON = angulas

Since AC = OC – OA = ON – OA, therefore, writing x = AC, we have

Chheda ON = OA = angulas (1)

This is the formuls stated by Vaṭeśvara, Śrīpati, and Āryabhaṭa-2. See Vaṭeśvara-siddhānta (8/1/26), Siddhānta-śekhara (10/22) and Mahā- siddhānta (7/2)

Now we observe that: When the sita is equal to AW, the number of karaṇas elapsed since the beginning of the fortnight is 15 and when the sita is equal to CW the number of karaṇas elapsed since the beginning of the fortnight is K. From this we infer that

= = = t, say.

Taking t = 1, we get AC = 15 – K, so that 1) gives

Chheda ON = angulas,

Which is the form in which Mañjula states the value of chheda ON.

Sine Aw = 16 angulas, therefore t is actually equal to 1 + 1/15. In framing the above rule, it has been taken to be equal to 1 approximately.

Of the several commentaries of the Laghumānasa that we know only Yallaya has included this verse among the 60 verses of the Laghumānasa and has explained and illustrated it. It occurs also in the commentariy of Praśastidhara but without explanation by him, indicating it to be an interpolation. This verse, however, seems to be necessary, because the chheda defined here has been referred to and used in the next verse. It seems that Yallaya or some other commentator added this as considered necessary and to keep number of verses limited to 60, replaced verses 51-52 (giving visibility correction) by verse 53 (alternate method of the same correction).

शृङ्गोन्नतिपरिलेखनविधिः

बिम्बापरदिशो भगात् प्राग्वृद्धिश्शुक्लकृष्णयोः। शुक्लान्ताद्बिम्बमध्यस्पृक्छेदाग्राच्छेदनं छिदा॥५९॥

Laying off of Sita or Asita in the Diagram of the Moon

In the light fortnight the sita and in the dark fortnight the asita increases from the west point of the Moon’s disc to wards the east. (What is meant by saying this is: lay off the sita or asita from the west point towards the east, according as the fortnight is light or dark.) One should cut the Moon by a thread or a pair of compasses taking the centre at a distance equal to the chheda (defined in verse 58’ above) in the direction passing through the centre of the Moon’s disc from the point lying at the (inner) end of the sita (and radius equal to the chheda).

ग्रन्थोपसंहारः (Concluding Remark)

मानसाख्यं ग्रहज्ञानं श्लोकषष्ट्या मया कृतम्। भवन्त्यपयशोभाजः प्रतिकञ्चुककारिणः॥६०॥

This book, entitled Laghumānasa, which contains knowledge pertaining to the planets, has been written in 60 ślokas (verses in śloka of anuṣṭup meter) by me. Those who will imitate it or find fault with it shall earn a bad reputation.

Sūryadeva Yajvā explains the text as follows: “In other works on astronomy, the treatment of the subject matter being extensive (and the rules being lengthy) calculation is not possible mentally; for this reason, I have written this Karaṇa work (a hand-book on astronomy) entitled Mānasa (= mental calculation), a means of acquiring knowledge of planetary motion, in 60 ślokas only.The number of verses has been mentioned here to emphasize that the present work though dealing with many topics is really small in size. Those who will produce the counterfeit work in imitation of this work shall earn infamy. For, no body can know the rationales etc. of the rules given in this Karaṇa work written by me, and therefore, the learned people will easily know that such-and-such person has forged another work on the same subject by stealing the contents of this work. Thus, such authors shall certainly earn a bad reputation. They shall be called counterfeiters only.”

So also explains Yallaya: “The work, which is called Mānasa (mental), as it enables one to know the planetary motion mentally also without taking recourse to laborious computation, has been composed in 60 verses in anuṣṭup meter. What is meant is that whatever was stated by Sūrya and others in voluminous works has been told by me in a small work. Thus, all astronomy has been summarized by me in 60 verses, and as compared to others, I have produced a more accurate work agreeing with observations and involving lesser calculation. Those counterfeiters who want to imitate this work shall earn ill reputation. By (saying) this, the intention is that this science should be taught to a worthy pupil after having tested him in various ways. Otherwise, there will be counterfeiters. To impart knowledge to one who is liable to imitate is a fault."

So also says Śrīpati: "The secrets of astronomy should not be imparted to the counterfeiters, the ungrateful, the enemy of the learned, the degraded, the irreligious, the stupid, and the wicked. One who imparts (knowledge to such a person) loses his good deeds and longevity."

Parameśvara, on the other hand, says: "Those who will find fault in this Mānasa shall only earn a bad eputation. What is meant is this: Although the mandoccha etc. stated here (in this work) are a little different from those stated by Bhāskara-2 etc. even then this work should be studied by all as it follows other works and agrees with the observations."

Thus, according to Sūryadeva Yajvā and Yallaya, the pratikañchukakārins are the counterfeiter, whereas, according to Parameśvara, they are the fault finders. In fact, the counterfeiters and the fault-finders both come under the category of pratikañchukakārins.

इति लघुमानसे चन्द्रशृङ्गोन्नत्याधिकारो नवमः॥

Thus ends chapter 9 about Lunar Horns in Laghumānasa.

समाप्तोऽयं ग्रन्थः। The book ends here.