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SUPPLEMENT

THE LAGHUMĀNASA OF MAÑJULA

Critical Study, Text with English
Translation, Notes and Appendices
by K.S. Shukla

A CRITICAL STUDY OF THE LAGHUMĀNASA OF MAÑJULA

By

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FOREWORD

Astronomer Mañjula who was called Mañjāla and Mañjālaka also, ranks amongst the foremost astronomers of India and is believed to have been proficient in all branches of astronomy — theoretical, spherical and practical. The *Laghumānasa*, composed in A.D. 932, is the only work coming from his pen that has survived. It is a calendaric work and gives brief and simple methods involving less calculation and at the same time novel and unprecedented rules not known to earlier astronomers in the span of 60 verses in Anuṣṭubh metre. This work, studied from Kashmir to Kerala, occupies an important place in the history of Indian astronomy, for it is the earliest work that employs the process of differentiation in finding the velocity of a planet and prescribes for the first time the lunar correction called "evection" in computations involving observation. Mañjula is also famous for rejecting the theory of oscillatory motion of the equinoxes taught by the earlier astronomers and advocating instead a progressive precessional motion giving the rate of precession as 59.9″ per annum.

The present study of the *Laghumānasa* was taken up by Prof. K.S. Shukla who had earlier edited the *Āryabhaṭīya* of Āryabhaṭa I (born A.D. 476) and the *Vaṭeśvara-siddhānta* of Vaṭeśvara (A.D. 904) for the Academy. He has critically edited the Sanskrit text of the *Laghumānasa* on the basis of 11 manuscripts procured from the various sources and has translated it into English along with explanatory and critical notes and comments and relevant appendices. In the introduction he has thrown ample light on the author and his scoliasts and on the popularity of the *Laghumānasa*.

It is hoped that this publication will prove useful towards a better understanding of the development of astronomy in medieval times and will serve as a book of reference to the scholars interested in the field.

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Science, INSA, New Delhi.

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K.S. SHUKLA

Āryabhaṭo grahagaṇitaṃ golaṃ dāmodaro vijānāti |
Yantrajño jiṣṇusuto sarvaṃ jānāti mañjulācāryaḥ ||

"Āryabhaṭa knows planetary astronomy, Dāmodara spherical astronomy, and Jiṣṇusuta (Brahmagupta) practical astronomy, but Mañjulācārya knows all of them."

CONTENTS

TRANSLITERATION

Vowels

Short:	अ	इ	उ	ऋ			
	a	i	u	ṛ			
Long:	आ	ई	ऊ	ए	ओ	ऐ	औ
	ā	ī	ū	e	o	ai	au

Anusvāra: ं = ṃ
Visarga: : = ḥ
Non-aspirant: ऽ = '

Consonants

Classified:	क्	ख्	ग्	घ्	ङ्			
	k	kh	g	gh	ṅ			
	च्	छ्	ज्	झ्	ञ्			
	c	ch	j	jh	ñ			
	ट्	ठ्	ड्	ढ्	ण्			
	ṭ	ṭh	ḍ	ḍh	ṇ			
	त्	थ्	द्	ध्	न्			
	t	th	d	dh	n			
	प्	फ्	ब्	भ्	म्			
	p	ph	b	bh	m			
Unclassified:	य्	र्	ल्	व्	श्	ष्	स्	ह्
	y	r	l	v	ś	ṣ	s	h
Compound:	क्ष्	त्र्	ज्ञ्					
	kṣ	tr	jñ					

ABBREVIATIONS

Ā	Āryabhaṭīya of Āryabhaṭa I (A.D. 499)
Bhā	Bhāsvatī of Śatānanda (A.D. 1099)
BṛSaṃ	Bṛhatsaṃhitā of Varāhamihira (d. A.D. 587)
BrSpSi	Brāhma-sphuṭa-siddhānta of Brahmagupta (A.D. 628)
GaĀ	Gaṇakānanda of Sūryācārya (A.D. 1460)
GA	Grahaṇāṣṭaka of Parameśvara (A.D. 1431)
GCN	Grahacāra-nibandhana of Haridatta (or Haradatta)
GGB	Graha-gaṇita-bhāskara of Tamma Yajvā (A.D. 1613)
GL	Graha-lāghava of Gaṇeśadaivajña (A.D. 1520)
GM	Grahaṇa-maṇḍana of Parameśvara (A.D. 1431)
KA	Karaṇāmṛta of Citrabhānu (A.D. 1530)
KK	Khaṇḍa-khādyaka of Brahmagupta (A.D. 665)
KKM	Karaṇa-kamala-mārtaṇḍa of Daśabala (A.D. 1058)
KKu	Karaṇa-kutūhala of Bhāskara II (A.D. 1183)
KU	Karaṇottama of Acyuta (d. A.D. 1621)
LBh	Laghu-bhāskarīya of Bhāskara I (A.D. 629)
LG	Lalla's Gola
LMā	Laghu-mānasa of Mañjula (A.D. 932)
MBh	Mahā-bhāskarīya of Bhāskara I (A.D. 629)
MSā	Makaranda-sāraṇī of Makaranda (A.D. 1478)
MSi	Mahā-siddhānta of Āryabhaṭa II (c. A.D. 950)
PG	Pāṭī-gaṇita of Śrdhara (c. 750 A.D.)
PSi	Pañca-siddhāntikā of Varāhamihira
RāMṛ	Rāja-mṛgāṅka of Bhoja (A.D. 1042)
ŚiDVṛ	Śiṣya-dhī-vṛddhida of Lalla
SiSā	Siddhānta-sāra of Mallaya Yajvā (A.D. 1596)
SiSaṃ	Siddhānta-saṃgraha of Vīrasūri (A.D. 1606)
SiSe	Siddhānta-śekhara of Śrīpati (c. A.D. 1039)
SiŚi	Siddhānta-śiromaṇi of Bhāskara II (A.D. 1150)
SūSi	Sūrya-siddhānta
Triś	Triśatikā of Śrīdhara
VJ	Vedāṅga-jyotiṣa
VSi	Vaṭeśvara-siddhānta of Vaṭeśvara (A.D. 904)

INTRODUCTION

The present work deals with the astronomer Mañjula and his Laghumānasa. It gives the Sanskrit text of the Laghumānasa critically edited on the basis of eleven manuscripts procured from different sources as well as its English translation which is furnished with explanatory and critical notes and comments.

1. The Author

1.1. Mañjula or Muñjāla

The real name of the author of the Laghumānasa seems to be Mañjula (meaning "lovely, beautiful, charming, etc.") and it is this name by which the earlier writers have referred to him. For example, astronomer Praśastidhara who wrote his commentary on the Laghumānasa in A.D. 958, only 26 years after the composition of that work, refers to him by the name Mañjula.

The name Muñjāla or Muñjālaka occurs for the first time in Sūryadeva Yajvā's commentary on the Laghumānasa, which was written about A.D. 1248. Due to the wide popularity of this commentary, the name Mañjula fell into the background and the name Muñjāla became popular. And now, particularly in South India, he is generally known by the name Muñjāla. The celebrated Bhāskara II (A.D. 1150) also has called him by this name.[1] The same name appears in Munīśvara's commentary on the Siddhānta-śiromaṇi.[2]

However, the astronomers of Āndhra Pradeśa have called him by the name Mañjula even up to the sixteenth century A.D. For example, astronomer Yallaya who flourished about A.D. 1482 and astronomer Tamma Yajvā who flourished about A.D. 1599 have referred to him by the name Mañjula.

In the present work, we have preferred to call him by his real name, viz. Mañjula.

1.2. His personal history

From the opening verse of the Laghumānasa we learn that Mañjula was a Brāhmaṇa and belonged to Bharadvāja Gotra. He calls himself "best among the Brāhmaṇas", which probably implies that he was a Brāhmaṇa of high rank, or, as inferred by the commentator Yallaya, that besides being a Brāhmaṇa he was an Ācārya, a teacher by profession.

As regard his ancestry, parentage, education, etc., Mañjula does not say anything. His commentators too are silent on these points.

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[1]See SiŚi (= Siddhānta-śiromaṇi), Golādhyāya, Golabandhādhikāra, vs. 18.

[2]See com. on Golādhyāya, Golabandhādhikāra, vs. 18.

1.3. His date

The date of Mañjula may be inferred from the epoch of calculation adopted by him in the Laghumānasa. This is Saturday noon, the beginning of Caitra, Śaka 854, which corresponds to Saturday noon, March 10, A.D. 932. It follows that the composition of the Laghumānasa must have been started sometime in A.D. 932. Mañjula, therefore, must have been born sometime towards the beginning of the tenth century A.D.

We know that astronomer Vaṭeśara was born in A.D. 880 and wrote his Karaṇasāra at the age of 19 years in A.D. 899 and his Siddhānta at the age of 24 years in A.D. 904. If Mañjula also wrote his Laghumañasa at the age of about 20 years, he must have been born about A.D. 912 when Vaṭésvara had already written his works. These works must have been available to Mañjula and he might have borrowed the second lunar correction which accounts for the evection and the deficit of the Moon's equation of the centre from some work of Vaṭeśvara, as Yallaya says. This work of Vaṭeśvara, however, is not available to us at present.

There is a great uncertainly regarding the date of astronomer Lalla, but as Vaṭeśvara wrote his Gola on the model of Lalla's Gola and borrowed profusely from him he undoubtedly lived anterior to Vaṭésvara. There are reasons to believe that Mañjula too borrowed from Lalla. For example, Mañjula's rules for finding the mean longitudes of Mars etc. are exactly the same as those found in certain manuscripts of the Śiṣya-dhī-vṛddhida of Lalla. According to the commentator Sūryadeva Yajvā the rule stated by Mañjula for finding parallax in longitude is exactly the same as stated by Lalla. Sūryadeva Yajvā has cited the passage from Lalla's work giving this rule. This shows that Lalla was a predecessor of both Vaṭeśvara and Mañjula. Astronomer Śrīpati, who comes next to Mañjula, has actually referred to Lalla among the astronomers who lived anterior to him and wrote astronomical Tantras.

1.4. His place

Mañjula does not mention the place of his birth or activity but from the mention of the word "prakāśa" in the opening verse of the Laghumānasa it is generally surmised that he belonged to the town called Prakāśa-pattana which was situated somewhere in northern India. Thus the commentator Sūryadeva Yajvā, in the opening remarks of his commentary on the Laghumānasa, says:

> "The Karaṇa called Mānasa was written by Ācārya Muñjālaka who resided in the town of Prakāśa-pattana situated in the northern part of the country (uttaradeśa) and was proficient in all the branches of Jyotiṣāśāstra."

So also says the commentator Yallaya:

> "The town bearing the name Prakāśa exists in the northern part of the country (uttaradeśa)."

But where in northern India was the town Prakāśa or Prakāśa-pattana located? We have no knowledge of any Prakāśa-pattana existing in northern India at present. But it seems that such a town did exist in the twelfth century A.D. Mallikārjuna Sūri, in his commentary on the Śiṣya-dhī-vṛddhida of Lalla, makes mention of this town and performs calculations for this place.[1] According to him, the town called Prakāśa-pattana (or Prakāśa-paṭṭaṇa) was situated 80 yojanas (or 9°40′) to the east of the Hindu prime meridian and the equinoctial midday shadow at that place measured 5¾ aṅgulas. Calculation from this data shows that this town must have been situated in latitude 25°36′ N. and longitude 85°6′E.[2] That is, it must have been located somewhere near Patna (lat. 25°22′ N., long. 85°8′ E.)

Mallikārjuna Sūri has calculated the times of beginning and end of the malignant phenomenon called Vaidhṛta which occurred at Prakāśa-pattana on Tuesday, the 2nd tithi of the light half of the month Caitra in the Śaka year 1107 (i.e., on Tuesday, March 5, A.D. 1185). It seems that Mallikārjuna Sūri lived at that place while writing his commentary on the Śiṣya-dhī-vṛddhida of Lalla in which he has mentioned Prakāśa-pattana and has made calculations for that place.

Mañjula's Prakāśa-pattana might have been the same as mentioned by Mallikārjuna Sūri.

It may, however, be added that Mañjula's Prakāśa-pattana, according to the commentators, had a temple of the Sun-god which was famous all around, and that in the regional dialect of that place the word mañjula was used as a synonym of the Sun. It is not possible to confirm this in the case of Mallikārjuna Sūri's Prakāśa-pattana.

1.5. His school

Mañjula does not strictly belong to any particular school of astronomy but more generally he is a follower of Āryabhaṭa I. While computing the initial constants for the Laghumānasa and also while formulating the rules for computing the mean longitudes, stated in the Laghumānasa, he generally adopts the revolution-numbers (bhagaṇas) given by Āryabhaṭa I, although sometimes he makes use of those given by Brahmagupta in his Brāhma-sphuṭa-siddhānta or those stated in the Sūrya-siddhānta. The commentators Sūryadeva Yajvā and Yallaya have shown that the revolution-numbers adopted by Mañjula are as follows:

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[1]See Mallikārjuna Sūri's commentary on ŚiDVṛ, xii. 11-12.

[2]Following Lalla we have taken the equatorial circumference of the Earth as equal to 3300 yojanas and the Hindu prime meridian as the meridian of Ujjain (long. 75°26′ E.). Unfortunately, the position of the Hindu prime meridian is not well defined in Hindu works. Although all Hindu authorities take it as passing through Ujjain, they do not appear to take it as identical with the meridian of Ujjain as we now know it.

Planet	*Revolutions in a yuga*	*Revolutions in a kalpa*	*Taken from*
Sun	43,20,000		Ā
Moon	5,77,53,336		Ā
Moon's apogee	4,88,219		Ā
Moon's asc. node	2,32,226		Ā
Mars	22,96,824		Ā
Śīghrocca of Mercury	1,79,37,020		Ā
Jupiter	3,64,224		Ā
Śīghrocca of Venus	70,22,376		SūSi
Saturn		14,65,67,298	BrSpSi

For details see infra, notes on LMā, i. 1′ to 5′.

2. Works of Mañjula

The Laghumānasa is the only work of Mañjula that has survived. But the adjective "laghu" prefixed to "mānasa" seems to suggest that Mañjula probably wrote two works on astronomy, called Mānasa, viz. (1) Bṛhan-mānasa or Mahā-mānasa (i.e., large Mānasa) and (2) Laghu-mānasa (i.e., small Mānasa). The use of the adjective "anyat" qualifying "laghumānasa" in the opening verse of the Laghumānasa also seems to suggest that Mañjula was the author of one more work on astronomy, called Mānasa, besides the Laghumānasa.

Commenting on the word "anyat", Praśastidhara says:

"Anyat. Another work called Bṛhanmānasa does exist; it is large and detailed."

According to the commentator Yallaya, by using the word "anyat" Mañjula says:

"Earlier, a work called Bṛhanmānasa was written (by me). Now I am writing another work on astronomy called Laghumānasa, which is different (from that)."

The commentator Parameśvara too interprets "anyat" in the same way.

The commentator Sūryadeva Yajvā interprets "anyat" in a different way but he mentions Mahā-mānasa and believes in the existence of that work.

Apart from what has been said above, we do not have any definite evidence regarding the existence of the Bṛhanmānasa. No posterior astronomer has referred to this work nor has quoted from it. Munīśvara (A.D. 1646), in his commentary on the Siddhānta-śiromani[1] of Bhāskara II (A.D. 1150), ascribes the following verses to Muñjāla:

[1]Golādhyāya, Golabandhādhikāra, vs. 18.

Uttarato yāmyadiśāṃ yāmyāntāt tadanu saumyadigbhāgam ।
Parisaratam gaganasadām calanam kiñcid bhavedapame ॥
Viṣuvadapakramamaṇḍalasampāte prāci meṣādiḥ ।
Paścāttulādiranayorapakramāsambhavaḥ proktaḥ ॥
Rāśitrayāntare'smāt karkādiranukramānmṛgādiśca ।
Tatra ca paramā krāntirjinabhāgamitā'tha tatraiva ॥
Nirdiṣṭo'yanasandhiścalanaṃ tatraiva sambhavati ।
Tadbhagaṇāḥ kalpe syurgorasarasago'ṅkacandramitāḥ ॥

Bhāskara II too has ascribed the revolutions of the ayanasandhi mentioned in the last verse cited above to Muñjāla. Although neither Bhāskara II nor his commentator Munīśvara ascribes these verses to the Bṛhanmānasa, it might be that these verses are taken from that work.

3. The Laghumānasa

3.1. Its nature

Jyotiṣaśāstra (or Science of Heavenly Bodies) is classified under three broad heads: (1) Gaṇita, (2) Jātaka or Horā, and (3) Śākhā or Saṃhitā. Of these, Gaṇita deals with reckoning with time (Kālakriyā i.e. computations involving time) and spherics (Gola i.e. treatment of positions and motions of the Earth, planets and asterisms with the help of the armillary sphere); Jātaka deals with the good and bad effects on men on the basis of planets occupying the twelve houses of the horoscope at the time of their birth or at the time of commencing some work; and Śākhā deals with the good and bad effects on the world on the basis of planetary positions and unusual phenomena perceived in nature. Thus Gaṇita may be described as astronomy, Jātaka as human astrology, and Saṃhitā as natural astrology.

Works on Gaṇita or astronomy are divided into three categories: (1) Siddhānta, (2) Tantra, and (3) Karaṇa. Those works that deal in detail with the various divisions of time and calculations of the planets and other astronomical matters taking the beginning of creation or kalpa (aeon) as the epoch of calculation are called Siddhānta; those works that deal with the calculation of the planets and other astronomical matters taking the beginning of Kaliyuga as the epoch of calculation are called Tantra; and those works that give simplified and short rules for the calculation of the planets and other astronomical matters taking the beginning of the year current at the time of composition of the work as the epoch of calculation are called Karaṇa. Siddhāntas may thus be described as comprehensive works on astronomy, Tantras as text-books on astronomy, and Karaṇas as manuals or hand-books on astronomy. The Karaṇas are essentially written for those who are engaged in the preparation of the Pañcāṅgas.

The Laghumānasa belongs to the category of Karaṇa works and was meant for the Pañcāṅga-makers.

3.2. Its text

The Laghumānasa consists altogether of 60 verses in Śloka or Anuṣṭubh metre and is the smallest Karana work available to us. The contents of the 60 verses are as follows:

Verse 1 is introductory and says that the author was a brāhmaṇa belonging to Bharadvāja Gotra and the Laghumānasa was meant to give brief and unprecedented methods of computations in astronomy.

Verse 2 says that if the week-day, the saṅkrānti-tithi, the positions of the Sun, Moon, the apogees of the planets for the beginning of Caitra of the year chosen as the epochal year, and the positions of the planets Mars etc., and their ascending nodes (including the ascending node of the Moon also) for the beginning of the mean solar year occurring in the epochal year, be known, the rules stated in the Laghumānasa will serve to give accurate results throughout one's life.

Verses 3-4 state how to find the so called Dyugaṇa.

Verses 5-10 give simplified rules for calculating the mean positions of the Sun, Moon, Moon's apogee, Mars, Śīghrocca of Mercury, Jupiter, Śīghrocca of Venus, Saturn, and Moon's ascending node.

Verse 11 defines the term Kendra and tells when the Bhuja and Koṭi are positive and when negative.

Verse 12 defines Bhuja and Koṭi and states how to calculate the Rsine of Bhuja or Koṭi.

Verse 13 gives the manda divisors, i.e., divisors to be used in the computation of the equation of the centre.

Verse 14 tells how to find the manda-phala (i.e., the equation of the centre) and the true-mean velocity of a planet.

Verses 15-16 give the śīghra divisors, i.e., the divisors to be used in finding the śīghra-phala (i.e., the second equation of the centre), and define the Śīghrocca of a planet.

Verse 17 tells how to find the true velocity of a planet.

Verses 18-19 deal with a special lunar correction which is comprised of the evection and the deficit of the Moon's equation of the centre. These verses tell how to find and apply this correction.

Verse 20 states how to find and apply the correction for the local longitude.

Verse 21 tells how to calculate Tithi, Karaṇa, Nakṣatra, and Yoga, which constitute four out of the five elements of the Hindu Pañcāṅga.

Verse 22 states how to find the ascensional difference of the Sun.

Verse 23 tells how to find the oblique ascensions of the tropical signs.

Verse 24 tells how to find Lagna (i.e., longitude of the rising point of the ecliptic) and the Iṣṭanāḍī (i.e., the corresponding time in nāḍīs etc.).

Verse 25 states how to obtain the length of the day and the Sun's hour angle.

Verse 26 tells how to find the midday shadow of the gnomon.

Verses 27-28 tell how to find the shadow of the gnomon for the given time.

Verses 29-30 state how to find the Sun's hour angle with the help of the day-length, the midday shadow, and the instantaneous shadow.

Verse 31 tells how to know whether conjunction, in longitude, of two planets is to occur or has already occurred.

Verse 32 states how to find the days elapsed since or to elapse before the conjunction, in longitude, of two planets.

Verse 33 states how to find the diameters of the Sun and the Moon.

Verse 34 tells how to obtain the diameter of Shadow, i.e., the diameter of the Earth's shadow cone at the Moon's distance.

Verse 35 tells how to find the diameters of the planets.

Verses 36-37 state how to find the latitudes of the Moon etc..

Verse 38 tells how to find the distance between the centres of two planets at the time of their conjunction in longitude. It also tells how to know whether one of the two planets occults the other.

Verse 39 states how to obtain parallax in longitude (lambana).

Verse 40 tells how to know the meridian ecliptic point (khārka).

Verse 41 states how to obtain parallax in latitude (nati).

Verse 42 tells how to apply the correction for parallax in latitude.

Verses 43-44 give the method for finding the semi-durations of an eclipse.

Verse 45 states how to know the times of contact and separation in a solar eclipse.

Verses 46-47 give the method for finding the akṣavalana and the ayanavalana.

Verses 48-50 describe how to construct the diagram of an eclipse.

Verses 51-52 state how to obtain the visibility corrections, akṣadṛkkarma and ayanadṛkkarma, and how to apply them.

Verse 53 tells how to find the position of the Sun when a planet rises heliacally (Udayārka) and the position of the Sun when a planet sets heliacally (Astārka).

Verse 54 tells how to find the Astārka and the Udayārka in the case of the star Canopus.

Verse 55 states how to find the true ascensional difference for a planet.

Verse 56 tells how long the phenomena of Vyatipāta and Vaidhṛta last.

Verse 57 tells how to find the Moon's shadow, i.e., the shadow cast by the gnomon due to moonlight.

Verse 58 (a-b) states how to obtain the measure of bright or dark part (sita or asita) of the Moon.

Verse 58 (c-d) tells how to find the true valana.

Verse 59 describes how to exhibit the bright or dark part of the Moon in the diagram.

Verse 60 is the concluding verse. The author gives here the number of ślokas in the book and warns the imitators telling them the consequences which they are liable to suffer.

3.21. Verses added and subtracted by Yallaya

The commentator Yallaya has dropped the verses 51 and 52 and has added two new verses numbered 53′ and 58′ in our edited text. The verse 53′ is meant to replace the rule for the visibility corrections stated in verses 51 and 52; and the verse 58′ is meant to supply the rule for finding the cheda referred to in verse 59. In Ms. G too, the verses 51 and 52 have been omitted and the verses 53′ and 58′ added.

3.22. Five verses in āryā metre giving the epochal constants

Besides the above-mentioned verses which form the main text of the Laghumānasa, the five verses in āryā metre, numbered 1′, 2′, 3′, 4′, and 5′ in our edited text, were also composed by Mañjula. These give the epochal constants needed in the computation of the Dyugaṇa and the mean positions of the planets. These epochal constants were computed for the time of composition of the Laghumānasa and were meant to serve for 100 years. The commentators who lived more than 100 years after Mañjula have replaced them by new verses giving constants for their own times. However, the commentators Praśastidhara, Sūryadeva Yajvā, and Parameśvara, who have ascribed the above-mentioned five verses to Mañjula, have mentioned and discussed them, although they have stated new epochal constants relevant to their own times.

In Ms. G, the verses 1′ to 5′ have been replaced by 9 new verses giving the same and some additional constants. However, the epochal day has been taken to fall on Sunday (ravivāsara) instead of Saturday (saurivāra). It means that according to Ms. G Caitrādi of Śaka 854 occurred on Sunday and not on Saturday as stated by Mañjula. According to Ms. F too Caitrādi of Śaka 854 occurred on Sunday, for in this manuscript vs. 1′ reads Sauravāra in place of Saurivāra. The commentator Sūryadeva Yajvā, too, seems to be of the same opinion, because to know the current week-day from the Dyugana calculated according to Mañjula he divides the Dyugaṇa by 7 and counts the remainder from Sunday (not from Saturday).

It is remarkable that verses 1′ to 5′ giving the epochal constants have been composed in āryā metre and not in anuṣṭubh metre in which the 60 verses of the Laghumānasa proper have been composed. This has been done, according to the commentator Sūryadeva Yajvā, for two reasons:

(1) To tell the reader that the epochal positions stated in those verses will not serve for ever but for 100 years only, and after every 100 years thereafter they will have to be replaced by new verses giving new epochal positions.

(2) To suggest that the new verses giving new epochal positions should also be composed in a metre different from the anuṣṭubh so that they may not be mixed up with the main verses of the Laghumānasa.

3.3. Chapterwise arrangement

The chapterwise arrangement of the 60 verses of the Laghumānasa is not the same in all the manuscripts. The commentator Praśastidhara arranges the verses under eight chapters as follows:

Chap. 1: Dhruvakanirūpaṇādhikāra.
Verses 1, 2, 1′ to 5′.

Chap. 2: Madhyagatyadhikāra.
Verses 3, 4, 5, 6, 7, 8, 9, and 10.

Chap. 3: Sphuṭagatyadhikāra.
Verses 11, 12, 13, 14, 15, 16 and 17.

Chap. 4: Prakīrṇādhikāra.
Verses 18, 19, 20, and 21.

Chap. 5: Tripraśnādhikāra.
Verses 22, 23, 24, 25, 26, 27, 28, 29 and 30.

Chap. 6: Grahayuti-grahaṇadvaya-parilekhanādhikāra.
Verses 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, and 50.

Chap. 7: Grahodayāstādhikāra.
Verses 51, 52, 53, 54 and 55.

Chap. 8: Mahāpātenduśṛṅgonnatyadhikāra.
Verses 56, 57, 58, 59 and 60.

The commentator Sūryadeva Yajvā arranges the verses under four chapters as follows:

Chap. 1: Sec. 1: Madhyamādhikāra.
Verses 1′ to 5′, 1 to 10.

Sec. 2: Sphuṭagatyadhikāra.
Verses 11 to 17.

Sec. 3: Prakīrṇakādhikāra.
Verses 18 to 21.

Chap. 2: Tripraśnādhyāya.
Verses 22 to 30.

Chap. 3: Grahaṇādhyāya.
Verses 31 to 50.

Chap. 4: Grahodayāstamayādhikāra.
Verses 51 to 60.

The commentator Parameśvara follows Sūryadeva Yajvā but he gives the name Saṃkīrṇādhikāra to the fourth chapter and includes verse 53′ in this chapter and comments on it, although he does not number this verse. He seems to be doubtful about the authenticity of this verse, for he remarks that some people omit this verse.

The commentator Yallaya, like Praśastidhara, divides the verses under eight chapters but his arrangement is as follows:

Chap. 1: Madhyagrahādhikāra.
Verses 1 to 10, and 20.

Chap. 2: Grahasphuṭādhikāra.
Verses 11 to 19, and 21.

Chap. 3: Tripraśnādhikāra.
Verses 22, 23, 24, 25, 26, 27, 28, 29 and 30.

Chap. 4: Grahaṇa-grahayuti-parilekhanādhyāya.
Verses 31 to 50.

Chap. 5: Grahodayāstādhikāra.
Verses 53, 53′, 54 and 55.

Chap. 6: Mahāpātādhikāra.
Verse 56.

Chap. 7: Candracchāyādhikāra.
Verse 57.

Chap. 8: Chandraśṛṅgonnatyadhikāra.
Verses 58′, 58, 59 and 60.

As already stated, Yallaya has dropped verses 51 and 52 and added verses 53′ and 58′.

Bhūdhara's commentary as far as it goes follows Yallaya.

3.4. Object of writing the Laghumānasa

The object of writing the Laghumānasa, as stated in the opening lines of this work, was to give simple and brief rules involving less calculation and at the same time new and unprecedented methods not known to earlier astronomers. The author has remarkably succeeded in his aim. All the rules stated by him, besides being short and simple, are highly ingenious and entirely original. As far as originality and scholarship is concerned, he remains unsurpassed by any other Indian astronomer and has rightly been proclaimed as the all-knowing astronomer, proficient in all branches of astronomy — theoretical, spherical and practical.

3.5. Special features

1. Dyugaṇa and mean positions of planets etc. (Vss. 3-4, 5-10)

The mean longitudes of the planets etc. are usually obtained from the Ahargaṇa, i.e., the number of days elapsed since the epoch. Mañjula uses a new device. Instead of obtaining the Ahargaṇa, he finds the so called Dyugaṇa, which is shorter than the Ahargaṇa by 357 times the number of years elapsed since the epoch. Moreover, the rule for finding the Dyugaṇa is so devised that it involves small numbers and easy calculation. The rules formulated for obtaining the mean longitudes of the planets etc. too are short and simple.

To find the mean positions of the Sun, Moon and planets etc., he uses two different methods. In the case of the Sun, Moon, and the Moon's apogee, he first finds the mean motion since noon on the Caitrādi tithi of Śaka 854 (which he chooses as the epoch of calculation) and then adds to it the mean longitude at the epoch. In the case of Mars, Śīghrocca of Mercury, Jupiter, Śīghrocca of Venus, Saturn, and the Moon's ascending node, he first finds the mean motion since the end of the mean solar year falling in Śaka 854 and then adds to it the mean longitude at the end of that mean solar year in the first five cases and subtracts it from the mean longitude at the end of that mean solar year in the last case.

2. The Jyā (or Rsine) table. (Vs. 12c-d)

To find the Jyā (or Rsine), Mañjula gives the following short table for radius 488′:

Jyā (1 sign) = $4^\circ 4'$
Jyā (2 signs) = $7^\circ 7'$
Jyā (3 signs) = $8^\circ 8'$

which gives fairly good results and is easy to remember and apply.

3. A special lunar correction to account for the "evection" and the deficit of the Moon's equation of the centre. (Vss. 18-19)

Mañjula is the earliest Hindu astronomer to have prescribed this correction. It is noteworthy that the related velocity correction is obtained by differentiating the longitude-correction formula.

The commentator Yallaya has ascribed this correction to the Vaṭeśvara-siddhānta, but it is not found to occur in the Vaṭeśvara-siddhānta available to us.

4. Correction of planets. (Vss 11-17)

To obtain the true longitude of a planet the following corrections have been prescribed by Mañjula to its mean longitude:

(1) Equation of the centre (mandaphala).

(2) Śīghraphala (only in the case of the five planets, Mars, Mercury, Jupiter, Venus, and Saturn).

(3) Evection and deficit of the Moon's equation of the centre (in the case of the Moon). This correction is used in the computation of eclipses, conjunction of heavenly bodies with the Moon, Moon's shadow, elevation of Moon's horns, etc., where observation is involved.

(4) Correction for the local longitude (deśāntara).

The cara-correction has not been prescribed because in the Laghumānasa the longitude is obtained for midday and the cara-correction for midday happens to be zero.

The bhujāntara-correction (i.e., correction for the equation of time due to the eccentricity of the ecliptic) has been omitted by Mañjula, probably because it is generally negligible. It is, however, not zero, because true noon and mean noon do not occur at the same time. Brahmagupta (in his Karaṇa Khaṇḍakhādyaka) has prescribed this correction in the case of Moon only. Its value in the case of the Moon is stated there to be one-twentyseventh of the Sun's equation of the centre. Mañjula has neglected this also.

It may be added that in finding the mandaphala and the śīghraphala Mañjula slightly differs from the other astronomers. He has modified the formulae given by the earlier astronomers empirically on the basis of observation. Moreover, he has applied the mandaphala and śīghraphala corrections only once.

5. Precession of the equinoxes. (Vs. 5′)

Mañjula takes Śaka 444 or A.D. 522 as the year when the precession of the equinoxes was zero and 1′ as the rate of precession per annum, so that in Śaka 854 or A.D. 932 it amounted to 6°50′ as stated by him.

Astronomer Munīśvara (A.D. 1646) has ascribed to Mañjula a passage[1] according to which the vernal equinox makes 199669 revolutions (westwards) in a period of 4320000000 years, which means that the rate of precession per year amounts to 59″.9. Bhāskara II (A.D. 1150) has also attributed these revolutions of the vernal equinox to Mañjula. It is curious that not a single commentator of the Laghumānasa either refers to

[1]See supra, under Sec. 2.

this passage nor to the rate of precession implied therein. The commentator Sūryadeva Yajvā simply refers to the traditionists according to whom the vernal equinox moves to and fro to the extent of 24° on either side.

6. Midday shadow, shadow for desired time, and hour angle obtained from these shadows. (Vss. 26, 27-28, 29-30)

The rules prescribed by Mañjula in these cases are new and his own. They became popular and were adopted by several later astronomers. (See Sanskrit Text, Appendix 4).

7. Diameters of the Sun, Moon, and the planets as well as the latitudes of the planets. (Vss. 33-35, 36-37)

Mañjula gives extraordinary rules which are typically his own.

8. Parallax in longitude (lambana) and parallax in latitude (nati). (Vss. 39 and 41)

In these cases too, Mañjula gives new and extraordinary rules which became popular and were adopted in several later works.

According to the commentator Sūryadeva Yajvā, the rule prescribed by Mañjula to obtain parallax in longitude was given earlier by Lalla, but this rule does not occur in the Śiṣya-dhī-vṛddhida, the extant work of Lalla.

Mañjula's rules in the case of the following determinations are also new and his own:

9. Semi-durations of eclipse obtained without the process of iteration. (Vss. 43-44)

10. Akṣavalana and ayanavalana. (Vss. 46-47)

11. The visibility corrections. (Vss. 51, 52, and 53')

12. The Astārka and Udayārka of Canopus. (Vs. 54)

13. True cara. (Vs. 55)

14. Durations of Vyatīpāta and Vaidhṛta. (Vs. 56)

15. The bright and dark portions (sita and asita) of the Moon. (Vs. 58)

16. Radius of the arc dividing the bright and dark portions of the Moon. (Vs. 58')

3.6. New corrections introduced in Mañjula's astronomy

The following two corrections were introduced in Mañjula's astronomy sometime after Śaka 1100 or A.D. 1178.

1. *The Caitrādi correction*

Let T denote the number of tithis elapsed since the Caitrādi of the current year, then the Caitrādi corrections are as stated in the following table:

Planet	Caitrādi correction in mins.
Sun	− T/149
Moon	− T/141
Moon's apogee	+ T/61
Moon's asc. node	Nil

2. *The Bīja correction (epoch Śaka 1100)*

Let Y be the number of years elapsed since Śaka 1100, then the Bīja corrections are as given in the following table:

Planet	Bīja correction in mins.
Sun	Nil
Moon	+ 10Y/200
Moon's apogee	− 10Y/80
Moon's asc. node	− 10Y/127
Mars	− 10Y/51
Śīghrocca of Mercury	+ 10Y/6
Jupiter	− 10Y/59
Śīghrocca of Venus	+ 10Y/13
Saturn	− 10Y/144

It is not known as to when and by whom these corrections were devised and introduced. The epoch of the Bīja correction, viz. Śaka 1100, however, is significant. It is the epoch used in making calculations by Mallikārjuna Sūri in his commentaries on the Sūrya-siddhānta and the Śiṣya-dhī-vṛddhida of Lalla. The initial constants for Mañjula's astronomy using Śaka 1100 as the epoch which occur in Mss. H_1 and H_2 and have been used in the manuscript entitled Laghumānasarītyā Sūryacandragrahaṇānayanam were also probably due to Mallikārjuna Sūri. For, Mallikārjuna Sūri seems to have made significant contributions to Mañjula's astronomy, and his views on the rules stated in the Laghumānasa have been occasionally cited by Yallaya. It is likely that the Caitrādi and Bīja corrections were devised and introduced in Mañjula's astronomy by some scholiast of Mallikārjuna Sūri.

The above-mentioned corrections have been used in one manuscript entitled Laghumānasarītyā Sūryacandragrahaṇānayanam in the calculation of the solar eclipse that occurred in Āndhra Pradeśa at a place located in latitude 14°15′N[1]. and longitude 22 yojanas to the east of the Hindu prime meridian on Monday, Māgha Amāvāsyā, Śaka 1528 (i.e., Monday, February 16, A.D. 1606) and in another manuscript in the calculation of the lunar eclipse that occurred in Āndhra Pradeśa at a place located in latitude 14°15′N. and longitude 38 yojanas to the east of the Hindu prime meridian on Thursday, Pauṣa Pūrṇimā, Śaka 1549 (i.e., Thursday, January 10, A.D. 1627). These corrections have been stated also in the interpolatory verses that occur in Mss. H_1 and H_2.

It seems that the Pañcāṅga-makers in Āndhra Pradeśa who prepared their Pañcāṅgas on the basis of the Laghumānasa took Caitrādi of Śaka 1100 as the epoch of their calculation and applied the above-mentioned corrections to the mean longitudes of the planets.

The question is: Why were the Caitrādi and Bīja corrections introduced in Mañjula's astronomy? To us it seems that these corrections were meant for those who wanted to use the epochal constants for Caitrādi, Śaka 1100, not only for 100 years thereafter, as taught by Mañjula, but for all times to come. We actually find that use of the epochal constants for Caitrādi of Śaka 1100 has been made as late as Śaka 1528 and Śaka 1549, and it is these people who have used the above corrections.

4. Scholiasts of Mañjula

Of the scholiasts of Mañjula, we know of the following who wrote commentaries on the Laghumānasa, or revised the epochal constants of that work, or introduced new corrections or refinements in the system of Mañjula's astronomy, or prepared Pañcāṅgas following the Laghumānasa:

(1) Praśastidhara (A.D. 958). Sūryadeva Yajvā has misspelt his name as Praśastadhara.

(2) Sūryadeva Yajvā (A.D. 1248). Also called Sūryadeva Dīkṣita, Sūryadeva Somasut, and Sūryadeva Sūri.

(3) Parameśvara (A.D. 1409).

(4) Yallaya (A.D. 1486). Also called Ellaya.

(5) Bhūdhara (A.D. 1572).

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[1]Corresponding to equinoctial midday shadow equal to 3 aṅgulas 30 vyaṅgulas.

(6) An anonymous commentator hailing from Karṇāṭa Deśa (Karnatak State or Mysore).

(7) Ayyalu Somayāji Bālaya (A.D. 1695), who wrote a commentary in Telugu.

(8) Puthumana Somayāji (A.D. 1732), who is said to have written a commentary in Malayalam.

(9) Mallikārjuna Sūri (A.D. 1178)

(10) Makaranda (A.D. 1478).

(11) Author of Laghumānasarītyā Sūryacandragrahaṇānayanam (16th century A.D.)

The commentaries written by the first eight astronomers exist completely or partially. There are reasons to believe that the next two astronomers (Mallikārjuna Sūri and Makaranda) also wrote commentaries on the Laghumānasa but they seem to have been lost.

Five manuscripts of the Laghumānasa (H_1, H_2, I_1, I_2, and J) available to us give or make use of initial or epochal constants (pūrva-dhruvas) for Caitrādi noon, Śaka 1100. These constants were probably devised by Mallikārjuna Sūri, for initial constants for the same year were given by him in his commentaries on the Sūrya-siddhānta and the Śiṣya-dhī-vṛddhida of Lalla. Moreover, the following verses bearing relevance to the rules of the Laghumānasa have been quoted by the commentator Yallaya and ascribed by him to Mallikārjuna Sūri:

(1) Gataiṣyakhaṇḍayogārdhamantarārdhena saṅguṇāt ǀ
Bhāgādeḥ khāgnilabdhonaṃ bhogyajyā mānase sphuṭā ǁ

(2) Chedā jināśvino'gāṅkā ravīndvośchedau tāveva mānase ǀ
Gatisphuṭārdhamarkendvośchedau tāveva mānase ǁ
Koṭyardhasaṃskṛtau chedau ravīndvorbimbasādhane ǀ

These verses occur in Ms. H_1 also. Ms. H_2 too contains the second quotation and might have contained the first one also but the manuscript with us is broken there.

Similarly, Bhūdhara in his commentary on the Laghumānasa quotes the following verses giving initial constants for Caitrādi, Śaka 1400 (or A.D. 1478), the epoch of the Makaranda-sāraṇī, and refers to Makaranda-mānasa.

Caturdaśaśate 1400 śāke saṅkrāntitithayo jināḥ 24 ǀ
Rāśyādibudhamadhyāhne rave rudrāh śarā mahī 11, 5, 1 ǀǀ3 ǁ
Indoḥ śivā rasāstriṃśa 11, 6, 30 duccasyāṣṭau nṛpā ghanāḥ 8, 16, 17 ǀ
Ṣaḍarkatānā 6, 12, 49 bhaumasya jñasyeṣudhṛtivāyavaḥ 5, 18, 49 ǀǀ4 ǁ

Guroḥ khaṃ dhṛtayo rāmāḥ. 0, 18, 3 kṛtāmbudarasā bhṛgoḥ 4, 17, 6 ।
Śaneḥ samudrasūryābhraṃ 4, 12, 0 rāhorvedāḥ khamabdhayaḥ 4, 0, 4 ॥5 ॥
Mandoccāṃśā raverastanagā 78 atha kujāditaḥ ।
Aṣṭārkāḥ 128 khākṛtiḥ 220 śūnyaghanāḥ 170 khāṣṭau 80 khasiddhakāḥ 240 ॥6 ॥
Pātā daśaghnā bhaumādervedā 40 kṣi 20 gaja 80 ṣaḍ 60 diśaḥ 100 ।
Ayanaṃ tithayaḥ sārdhāḥ 15।30 *makarandoktamānase* ॥7 ॥

The Makaranda-mānasa might have been the Makaranda's edition of the Laghumānasa with revised initial constants.

5. Commentaries on the Laghumānasa

5.1. Commentaries in Sanskrit

5.11. Praśastidhara's commentary

Two manuscripts of this commentary exist in the Government Oriental Library, Mysore (now Oriental Research Institute, Mysore):

1. Ms. No. B 581 A. 10 ff. Incomplete. (2 Adhikāras only).
2. Ms. No. B 583. 30 ff. Complete.

A transcript in Devanāgarī characters of the complete manuscript (B 583) exists in the Lucknow University Library, Lucknow. Its accession no. is 47065. We have designated it as A_1.

This commentary begins and ends as follows:

Beginning:

Śrīḥ. Laghumānasavyākhyāprārambhaḥ. Śrīsūryanārāyaṇānya namaḥ.
Ekaṃ cāsti [ca] bahudhā yadbrahma paraṃ praṇamya tadbhaktyā ।
Laghumānasakaraṇasyātanute vivṛtiṃ *praśastidharaḥ* ॥
Alpaṃ granthamanalpaprayāsaracitaṃ parisphuṭaṃ vyāpi ।
Samadṛggaṇitamato me tadvivṛtāvasti bahumānaḥ ॥

Mānasākhyakaraṇaprārambhe'bhīṣṭadevatāṃ namaskṛtyādityapadena saṃkarta svakaraṇapravṛttau prayojanamāha —
Prakāśādityavatkhyāto bhāradvājo dvijottamaḥ ।
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam ॥1 ॥

End:

Pratisaṃhārārthaṃ ślokamāha —
Mānasākhyaṃ grahajñānaṃ ślokaṣaṣṭyā mayā kṛtam ।
Bhavantyapayaśobhājaḥ pratikañcukakāriṇaḥ ॥4 ॥

Mānasaṃ nāma grahajñānaṃ [grahagatisādhanaṃ] yena jñāyate tat. Ṣaṣṭisaṃkhyaiśślokairmayā kṛtam. Atra karaṇe [ye] puruṣāḥ pratikañcuka [kārıṇaste] apayaśobhājo bhavanti. Anena prakāreṇa grahaṇāt samyagvijānanti te yaśobhājo bhavantīti siddham.

Colophon:

Iti praśastidharācāryakṛtāyāṃ laghumānasavivṛtau mahāpātenduśṛṅgonnatyadhikāro'ṣṭamaḥ.

Iti laghumānasakaraṇaṃ savyākhyānaṃ samāptam.

This commentary is called Laghumānasavivṛti or Laghumānasavyākhyāna. It explains the text and illustrates the working of the rules by solving actual astronomical problems. It is the earliest known commentary on the Laghumānasa and was written only 26 years after the composition of the original text.

The commentator does not refer to any earlier author or work but quotes several passages without mentioning their authors or the sources from where they were taken.[1]

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[1]The passages quoted are:

(1) Antarayukte hīne bhānau candrādhike kramādūne |
Cakrone śata 100 guṇite svaranidhı 97 bhakte tu saṅkramatithiḥ syāt ||

Praśastidhara gives this verse after vs. 5' of our text as part of the text and explains it.

(2) Dhanarṇayorantarameva yogaḥ | (Quoted under vs. 7)

This quarter-verse occurs in the Siddhānta-śekhara (xiv. 3b) of Śrīpati and also in the Bījagaṇita (dhanarṇaṣaḍvidham, vs. 3d) of Bhāskara II. But Praśastidhara must have quoted it from some earlier work.

(3) Śūnyarṇyoḥ khadhanayoḥ khaśūnyayorvā vadhaḥ śūnyam |

(Quoted under verse 8a-b)

This hemistitch has been taken from Brahmagupta. See Brāhma-sphuṭa-siddhāanta, kuṭṭakādhyāya, section 2, parikarma-prakaraṇa, vs. 4 (c-d).

(4) Nakhācalaiḥ khakhagajaiḥ khakhebhaiḥ khāṅgavahnibhiḥ |
Tithyarkṣayogakaraṇā dyumānārdhāgataiṣyakam ||

(Interpolated after vs. 21)

(5) Four verses beginning with Tātkālikārka, occurring in Bina Chatterjee's edition of Khaṇḍakhādyaka. See Vol. II, pp. 89-90. These are due to Bhaṭṭotpala.

Praśastidhara does not give these verses in full. He simply refers to them by saying Tātkāliketyādi 4 śloka, and explains them in his com. on vs. 24 (a-b).

(6) Saumyakṣepo'dhiko jetā hīnakṣepastu dakṣiṇe |
Ubhayorekamārgaśced bhinnamārge jayottaraḥ ||

(Interpolated after vs. 39)

The commentator Yallaya also quotes this verse and explains it.

(7) Praviśati yad bhūcchāyāvṛttaṃ trairāśikāt svakakṣāstham |
Tena na lambanamindornāvanatistulyakakṣatvāt ||

(Interpolated after vs. 42)

This is vs. 31 of Golavāsanādhyāya of Lalla's Gola.

(8) Samāśayośśītakarārkayossyādbhārdhaṃ yutiścedayane vibhinne |
Yogo vyatīpāta ihānyadikkayostulye'yane maṇḍalasammite'paraḥ ||

(Interpolated after vs. 56)

A transcript in Devanāgarī characters of the incomplete manuscript (B 581 A) was procured for my use by Prof. K.V. Sarma from the Oriental Research Institute, Mysore. It has been designated as A_2. It begins and ends thus:

Beginning:

Laghumānasavyākhyā Praśastadharīyā
Śrīgaṇādhipataye namaḥ. Ādityādinavagrahadevatābhyo namaḥ. Avighnamastu.
Ekañcāsti [ca] bahudhā yadbrahma paraṃ praṇamya tadbhaktyā I
Mānasanāmani karaṇe kurute vivṛtiṃ praśastadharaḥ II
Alpaṃ granthamanalpaṃ sakalaṃ prayāsarahitaṃ parisphuṭaṃ vyāpi I
Samadṛggaṇitamato me tadvivṛtāvasti bahumānaḥ II

Mānasākhyakaraṇe prārambhe'bhīṣṭadevatāṃ namaskṛtyādityapadena saṅkīrtya svakaraṇpravṛtteḥ prayojanamāha —
Prakāśādityavatkhyāto bhāradvājo dvijottamaḥ I
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam II

End:

Bhuktyarthamasyaiva ravibhuktirnakhairbhaktaḥ 2157 punaḥ pañcāṅganetraiḥ bhaktaḥ 0113 anayoryogo rāhubhuktiḥ 3110.

Iti mānasakaraṇe madhyamādhikāro dvitīyaḥ I
Atha sphuṭādhikāro vyākhyāyate.

The two manuscripts, apart from the usual errors noticed in manuscripts, exhibit significant divergences at places. There are, for example, differences in the style of expression, and it seems that the two have come from the pens of two different scribes who have copied the original manuscript in their own way. These differences will be clear from the following illustrative passages culled from the two manuscripts.

This verse occurs also in Yallaya's commentary and in Ms. H_1. Yallaya mentions Vaṭeśvara-siddhānta as its source, but it is not found to occur in the Vaṭeśvara-siddhānta available to us.

(9) Viṣamapadagasya śaśinaḥ caramadhikaṃ cedraveścarādbhūtaḥ I
Pāto bhāvyūnaṃtadyadi samapadage'nyathā śaśinaḥ II
Ṛṇadhanasamaviṣamatayā yutivivaraṃ vaidhṛte'nyathā pāte I
Carayoḥ prathamo rāśiḥ sveṣṭaghaṭībhistathā'nyo'pi II
Dvāvapi bhūtaiṣyau ced tadantareṇāyathā haredyutyā I
Ādyeṣṭaghātamādyavadāptā nāḍyo sakṛttābhiḥ II
Niścalaghaṭikāguṇitā viṣuvacchāyā vibhājitā'dyena I
Pātasya madhyakālāt śodhyā yojyāstadādyantau II

(Quoted and commented under vs. 56)

These verse too, according to the commentator Yallaya, belonged to the Vaṭeśvara-siddhānta. But they are not found to occur in the Vaṭeśvara-siddhānta available to us.

(1) A_1 reads: Etāśca yathoktādityamadhyamaṃ cakrāt [12-0-0] viśodhya śiṣṭabhāgāṅkāssyuḥ.

A_2 reads: Etāśca tithayauktamādityamadhyamaṃ cakrādviśodhya ye caturdaśabhāgāḥ te eva saṅkrāntitithayaḥ.

(2) A_1 reads: Kṛtayamavasurasadaśakā daśāhatāśceti. Bhaumapātaḥ catvāriṃśadbhāgāḥ 40. Budhapāto viṃśatiḥ 20. Gurupāto'śītiḥ 80. Śukrapātaṣṣaṣṭiḥ 60. Śanipātaśśataṃ 100. Iti śeṣapātāṃaśāḥ.

A_2 reads: Kṛtayameti śiṣṭānāṃ bhaumādīnāṃ pātabhāgāḥ daśaguṇitāḥ. Tatra bhaumasya catvāriṃśat. Budhasya viṃśatiḥ. Guroraśītiḥ. Śukrasya ṣaṣṭiḥ. Śaneśśatam 40, 20, 80, 60, 100.

(3) A_1 reads: Aśītyadhikaśatāṣṭakamite 880 śakakāle ebhyaḥ kṛtaśararvasūn 854 dhruvakālikābdān viśodhya śiṣṭairiṣṭābdaiḥ 26 vakṣyamāṇavidhinānīto dyugaṇaḥ 227. Saptataṣṭaśeṣaḥ 3. Dhruvaśanyādiko gataḥ vartamāno bhaumavāra iti siddhaḥ. Asmāddyugaṇādvakṣyamāṇavidhinānīto madhyamārkaḥ 11-28-18. Candramadhyaḥ 0-2-17. Candroccaṃ 11-16-18. Atra madhyamārke cakrād 12-0-0 viśuddhvaiva śiṣṭāṃśā eva meṣasaṃkrāntitithī 2.

A_2 reads: Tatrāśītyadhikaśatāṣṭakamite śakakāle śakakālo yad dhruvābdaḥ 800 tebhyaḥ kṛtaśaravasūn 854 viśodhyābdagaṇaḥ 26 etaiḥ dhruvakālābdaiḥ vakṣyamāṇavidhinā dyugaṇaḥ 227. Atassaptavibhaktaḥ śeṣaṃ 3. Evaṃ bhaumavāre nibaddho yaddhruvakadyugaṇādvakṣyamāṇavidhinārkamadhyamaḥ rāśayaḥ ekādaśa 11 aṣṭāviṃśatibhāgāḥ 28 aṣṭādaśa liptāḥ 18 candramadhyamaḥ rāśiḥ śūnyaṃ o bhāgau dvau 2 liptāssaptadaśa 17 candroccarāśayaḥ ekādaśa 11 bhāgāḥ ṣoḍaśa 16 liptāḥ aṣṭādaśa 18. Madhyamārkaṃ cakrādviśodhya saṅkrāntitithī dvau 2.

(See com. on LMā, vss. 1'-4').

There are also significant textual reading-differences in the two manuscripts. For example:

(1) See LMā, vs. 3 (c-d)
Whereas A_2 reads: svaṣaṣṭyaṃśavivarjitaḥ
A_1 reads: svaṣaṣṭyonitāt svataḥ

(2) See LMā, vs. 9 (c-d).
Whereas A_2 reads: digghnāt ṣaḍbhiḥ sito digghnāt
A_1 reads: śukro'kṣaghnāt tribhirdigghnāt

(3) See LMā, vs. 10 (a-b),
Whereas A_2 reads: ṣaḍguṇādayutenārkiḥ
A_1 reads: trighnādārkiḥ khakhābhrākṣaiḥ

The readings given in Ms. A_2 are those commented upon by the commentator Praśastidhara.

The commentator Praśastidhara hails from Kashmir. He calculates the positions of the Sun, Moon, etc., for a place in Kashmir, which was situated 99 yojanas to the east of the Hindu prime meridian passing through Ujjain. The equinoctial midday shadow at that place has been stated to be 8 aṅgulas 7 vyaṅgulas or $8\frac{7}{60}$ aṅgulas, the same as stated in the Karaṇasāra of Vaṭeśvara. The latitude of Praśastidhara's place was likewise 34°N. approximately. According to Karaṇasāra, it was 34°9′N. That Praśastidhara belonged to Kashmir is confirmed by the testimony of the commentator Sūryadeva Yajvā who has called him a native of Kashmir (kāśmīravāsin).

Praśastidhara wrote his commentary on the Laghumānasa about A.D. 958, for he states the initial constants for Saturday noon, Caitrādi, Śaka 880 (or Saturday noon, February 20, A.D. 958). Other dates mentioned in the commentary are:

(1) Tuesday, 15th tithi of light half of Vaiśākha, Laukika Saṃvatsara 37, Saka 884 (i.e., Tuesday, April 22, A.D. 962).

(2) Wednesday, 15th tithi of dark fortnight of Śrāvaṇa, Laukika Saṃvatsara 42, Śaka 889 (i.e., Wednesday, August 7, A.D. 967).

(3) Tuesday, 2nd tithi of dark fortnight of Āṣādha, Laukika Saṃvatsara 36, Śaka 883 (i.e., Tuesday, July 2, A.D. 961).

(4) Monday, 14th tithi of light fortnight of Śrāvaṇa, Laukika Saṃvatsara 36, Śaka 883 (i.e., Monday, July 29, A.D. 961).

(5) Monday, 2nd tithi of light fortnight of Caitra, Laukika Saṃvatsara 37, Śaka 884 (i.e., Monday, March 10, A.D. 962).

All these dates (which have been stated in the order in which they occur in the commentary) fall within 10 years from Śaka 880 (A.D. 958).

Among the contemporaries of Praśastidhara may be mentioned the name of Bhaṭṭopala who too was an inhabitant of Kashmir and completed his commentary on the Bṛhatsaṃhitā of Varāhamihira on Thursday, Phālguna Kṛṣṇa 2, Śaka 888 (i.e., Thursday, February 14 A.D. 967) and his commentary on the Khaṇḍakhādyaka of Brahmagupta on Thursday, Caitra Śukla 5, Śaka 890 (i.e., Thursday, March 5 (?), A.D. 968).

5.12. Sūryadeva Yajvā's commentary

Three manuscripts of Sūryadeva Yajvā's commentary on the Laghumānasa are known to exist, two in the Government Oriental Manuscripts Library, Madras, and one in the Curator's Office Library, Trivandrum, (now Kerala University Oriental Research Institute and Manuscripts Library, Trivandrum):

1. Madras: Ms. No. R 2741. 190 ff. Grantha. Incomplete.

This manuscript contains Sūryadeva Yajvā's commentary from the very beginning and continues up to the commentary on vs. 5 of the last chapter (Grahodayāstamayādhikāra)[1] in the midst of which it breaks off.

2. Madras: Ms. No. R 3037. 20 ff. Grantha. Incomplete.

This manuscript contains Sūryadeva Yajvā's commentary from vs. 6 of the last chapter and runs up to the end.

3. Trivandrum: Ms. No. C. 729 E (C. 2121 E). 25 ff. Malayalam. Incomplete.

A transcript in Devanāgarī characters of the first two manuscripts, taken together, exists in A.N. Singh Collection (No. 35) in the Department of Mathematics and Astronomy, Lucknow University. The missing portion of the commentary on vs. 5 of the last chapter which forms the connecting link of the two manuscripts was recently supplied by Prof. K.V. Sarma from the third manuscript, a transcript of which is in his possession. Thus the transcript in A.N. Singh Collection now contains the full text of Sūryadeva Yajvā's commentary. We have designated this transcript as B.

This commentary begins and ends thus:

Beginning:

Śrīḥ. Laghumānasam. Śrīsūryadevakṛtavyākhyāvāsanāsahitam.
Adhyātmavidyāmupadeśayantaṃ dṛḍhaṃ prapannāya dhanañjayāya |
Pratodahastaṃ pragṛhītaraśmiṃ devaṃ prapadye vasudevasūnum || 1 ||
Skandhatrayārthaviduṣā sūryadevena yajvanā |
Mānasākhyagrahajñānavāsanādya pradarśyate || 2 ||

Dharmaṃ jijñāsamānānāṃ sākṣāt paramparayā arthadharmajñanopāyabhūtāni caturdaśavidyāsthānāni smaryante —

Purāṇanyāyamīmāṃsādharmaśāstrāṅgamiśṛtāḥ |
Vedāḥ sthānāni vidyānāṃ dharmasya ca caturdaśa ||

[1]This is vs. 55 of our edited text.

Tathā —

Aṅgāni vedāścatvāro mīmāṃsā nyāyavistaraḥ I
Purāṇaṃ dharmaśāstraṃ ca vidyā hyetāścaturdaśa II

Vedāṅgāni ca smaryante —

Śikṣā kalpo vyākaraṇaṃ jyautiṣaṃ niruktaśchandovicitiḥ I

Eṣāmaṅgaviśeṣaklṛptiśca smaryate —

Chandaḥ pādau tu vedasya hastau kalpo'tha paṭhyate I
Mukhaṃ vyākaraṇaṃ tasya jyautiṣaṃ netramucyate II
Śikṣā ghrāṇaṃ tu vedasya niruktaṃ śrotramucyate I

Tathā ca śrīpatiḥ —

Chandaḥ pādau śabdaśāstraṃ ca vaktraṃ
Kalpaḥ pāṇirjyautiṣaṃ cakṣuṣī ca I
Śikṣā ghrāṇaṃ śrotramuktaṃ niruktam I
Vedasyāṅgānyāhuretāni ṣaṭ ca II

Atra "svādhyāyo'dhyetavyaḥ", "svādhyāyamadhīyīta" ityādibhirvedavākyairarthajñānaparyantaṃ vedādhyayanaṃ vidhīyate. Arthajñanaparyantādhyayanavidhānasāmarthyāt vedārthajñānopāyabhūtānāmaṅgānāmadhyayanaṃ vihitam. Śrutiśca bhavati — "tasmād brāhmaṇena niṣkāraṇaṃ ṣaḍaṅgo vedo'dhyetavyaḥ" iti. Aṅgādhyayanakālaviśeṣaśca smaryate — "vedāṅgāni ca sarvāṇi kṛṣṇapakṣe ca saṃpaṭhet" iti. Tasmādupanītaistraivarṇikairvedārthajñānopāyabhūtāṅgādhyayanamapi svakāle kartavyam. Aṅgeṣvapi —

Mukhamardhaṃ śarīrasya sarvaṃ vā mukhamucyate I
Tatrāpi nāsikā śreṣṭhā śreṣṭhe tatrāpi cakṣuṣī II

Iti cakṣuṣaḥ prādhānyavacanāt cakṣuṣṭvena saṃsmṛtatvāt pradhāmasya jyotiṣākhyasya vedāṅgasyādhyayanamavaśyaṃ kartavyam. Tatra nānāśākhāsu viprakīrtitasya jyotirviṣayasya vedabhāgasyārthān saṃsmṛtyādau bhagavatā brahmaṇā bahuvistaraṃ jyotiśśāstram kṛtam. Brahmaṇaḥ sakāśādadhītatacchāstro Vṛddhagargaḥ tat saṃkṣipya saṃhitākhyamanyajjyotiaśśāstraṃ cakāra. Tasmāllabdhavidyāḥ Parāśarādayo munayo'pi anyāni jyotiśśāstrāṇi cakruḥ.

Evamupodghātaṃ pradarśya śāstraṃ vyākhyāyate. Tatra tāvadācāryo Muñjālaḥ svanivāsakīrtigotrajātiprayojanoktipurassaraṃ laghumānasakaraṇasyārambhamādyena ślokena pratijānīte —

Prakāśādityavatkhyāto bhāradvājo dvijottamaḥ ।
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam ॥1॥

End:

Atra prakriyodāharaṇādikaṃ praśastadharakṛtavivṛtyaiva jñatavyam. Granthavistarabhayānneha tatprapañcaḥ kriyate. Evamiyaṃ mānasavyākhāyāvāsanā sampūrṇeti siddham.

Viśvaśaśākakumbhārkahastarkṣajñaptajanmanā ।
Kathitā sūryadevana grahāstodayavāsanā ॥ iti.

Pūrvaṃ mayā kṛtā granthā anukramyante. Bhāskarācāryamahātantravivaraṇaṃ govindasvāmyāṃ prathamaṃ vyākhyātam. Atha āryabhaṭīyasya śāstrasya bhaṭaprakāśākhyaṃ saṃkṣyaṃ. Tato varāhḥamihirakṛtā mahāyārā saṃksepato vyākhyātā. Idaṃ mānasākhyaṃ karaṇaṃ mūlavāsanāsahita saṃkṣevavāsanāpradarśanārthaṃ vistareṇa vivṛtam. Idānīṃ śrīpatikṛtā jātakapaddhatirvyākhyātā. Tāvaddevī sarasvatī pūrayaṣyatīti siddham.

Itthaṃ mānasakaranaṃ vyākhyātaṃ sūryadevasomasutā ।
śrīsūryadevanāmnā mātrībhrātuḥ prasadena. ॥

Colophon:

Iti sūryadevasomasudviracite mānasavyākhyāne grahodayāstamayādhikāraśca-turthaḥ. Sampūrṇamidaṃ mānasavyākhyānam.

Sūryadeva Yajvā's commentary on the Laghumānasa, called Mānasavyākhyāna or Mānasavyākhyāvāsanā, is very large, detailed and comprehensive. It explains the text and gives the rationale of the basic rules (mūlavāsanā) as well as the rationale of the abridged rules as formulated by Mañjula (saṃkṣiptavāsanā). The commentary begins with a lengthy introduction throwing light on the importance, origin, nature, scope and development of Hindu astronomy. Other chapters also begin with a brief introduction. Although the commentary is very large, detailed and comprehensive it does not explain the procedure of working (prakriyā) by solving actual astronomical problems. For those who are interested in it, Sūryadeva Yajvā advises to consult the commentary written by Praśastidhara.

The commentary gives ample evidence of the commentator's wide reading and deep scholarship, and Yallaya has rightly called him all-knowing astronomer (sarvajña)[1]. The commentator refers to Lagadhācārya, Vṛddha Garga, Parāśara, Āryabhaṭa I, Haradatta (generally known as Haridatta), Lāṭadeva, Varāhamihira, Bhāskara I (whom he calls Bhāskarācārya), Brahmagupta, Lalla, Pṛthusvāmin (i.e., Pṛthūdaka Svāmī), Praśastidhara (whom he calls Praāastadhara), Bhaṭṭotpala, and

[1]See Yallaya's com. on SūSi, iv. 25.

Śrīpati. Reference is also made to Āryabhaṭa-siddhānta, Mahā-bhāskarīya, Laghu-bhāskarīya, Prabhākara-gaṇita, and Yogīśvara's Tantrapradīpa, which have been cited amongst works falling under the category of Tantra, and to Pañca-siddhāntikā and Khaṇḍakhādyaka, which have been mentioned amongst works falling under the category of Karaṇa.

There are quotations from the vedic, religious and philosophical works,[1] and from the writings of Lagadhācārya[2], Vṛddha Garga[3], Garga[4],

[1]The passages quoted are:

(1) Purāṇanyāyamīmāṃsādharmaśāstrāṅgamiśritāḥ. I
Vedāḥ sthānāni vidyānāṃ dharmasya ca caturdaśa II
(2) Aṅgāni vedāścatvāro mīmāṃsā nyāyavistaraḥ I
Purāṇaṃ dharmaśāstraṃ ca vidyā hyetāścaturdaśa II
(3) Vedāṅgāni ca smaryante "śikṣā kalpo vyākaraṇaṃ jyotiṣaṃ niruktaśchandovicitiḥ". Eṣāmaṅga-viśeṣaklṛptiśca smaryate —
Chandaḥ pādau tu vedasya hastau kalpo'tha paṭhyate I
Mukhaṃ vyākaraṇaṃ tasya jyotiṣaṃ netramucyate II
Śikṣā ghrāṇaṃ tu vedasya niruktaṃ śrotramucyate I
(4) "Svādhyāyo'dhyetavyaḥ"; "svādhyāyamadhīta"; "tasmādbrāhmaṇena niṣkāraṇaṃ ṣaḍaṅgo vedo'dhyetavyaḥ"; "vedāṅgāni ca sarvāṇi kṛṣṇapakṣe ca saṃpaṭhet".
(5) Aṅgeṣvapi —
Mukhamardhaṃ śarīrasya sarvaṃ vā mukhamucyate I
Tatrāpi nāsikā śreṣṭhā śreṣṭhe tatrāpi cakṣuṣī II
(6) "Kṛttikāsvagnimādadhīta"; "rohiṇyāmagnimādadhīta"; "punarvasvoragnimādadhīta"; "vaiśākhyāṃ paurṇamāsyāṃ yadi paśunā somena yajeta" tathā "phālgunyāṃ paurṇmāsyāṃ caitryāṃ vaiśvadevena yajeta", "āṣāḍhyāṃ śrāvaṇyāṃ vodavasāya varuṇapraghāsairyajeta"; "śaradi vājapeyena yajeta"; "amāvāsyā paurṇamāsyā upariṣṭādvyaṣṭakā tasyāmaṣṭamī jyeṣṭhayā saṃpadyate tāmekāṣṭakenety-ācakṣate saṃvatsarā yadi dīkṣiṣyamāṇā ekāṣṭākāyāṃ dīkṣeran" evamādyāḥ śrutayaḥ kāleṣu karmāṇi codayanti.
(7) Tathā ca nyāyavido vadanti — "kāle hi karma codyate na karmaṇi kāla" iti. Kālajñānābhāve karmā-nuṣṭhānaṃ na siddhyati. Tathā ca akāle kṛtasyāgnihotrahomasya kāle punaḥ karaṇaṃ prāyaścittamā-hāpastambaḥ — "yadi prāgastamayājjuhuyāt punarevāstamite hutvā.... manasā upatiṣṭheta yadi mahārātre punarevauṣadhīrhutvā etayaivopatiṣṭhete" ti mantreṇa karmaṇāṃ pradhānabhūtamaṅgapra-tipādakaṃ jyotiṣaśāstramavaśyamadhyetavyamiti siddham.

[2]The passages quoted are: VJ (Ārca), vss. 35-36; VJ (Yājuṣa), vss. 4 and 3 (with jyotiṣaṃ in place of gaṇitaṃ in vs. 4).

[3]The passages quoted are:

(i) Svayaṃ svayambhuvā dṛṣṭaṃ cakṣurbhūtaṃ dvijanmanām I
Vedāṅgaṃ jyotiṣaṃ brahmasamaṃ vedairvinissṛtam II
Mayā svayambhuvaḥ prāptaṃ kriyākālaprasādhakam I
Vedāṅgamuttamaṃ śāstraṃ trailokyahitakārakam II
Mattaścānyān ṛṣīn prāptaṃ pāramparyeṇa puṣkalam I
Taistathā ṛṣibhirbhūyo granthaiḥ svairudāhṛtam II
(ii) Gaṇitaṃ jātakaṃ śākhāṃ yo vetti dvijapuṅgavaḥ I
Triskandhajño vinirdiṣṭaḥ saṃhitāpāragaśca saḥ II

[4]The passages quoted are:

(i) Śrūyatāṃ svargyamāyuṣyaṃ dharmyaṃ puṇyaṃ yaśaskaram I
Jñānavijñānasampannaṃ dvijānāṃ pāvanaṃ param II
Kālajñānamidaṃ puṇyamādyaṃ vijñānamuttamam I
Sisṛkṣuṇā purā vedānetat sṛṣṭaṃ svayambhuvā II
Vedāṅgamādyaṃ vedānāṃ kriyāṇāṃ ca prasādhakam I

Āryabhaṭa I[1], Varāhamihira[2], Bhāskara I[3], Brahmagupta[4], Haradatta[5], Lalla[6], Śrīdhara[7],

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Jyotirjñānaṃ dvijendrāṇāmato vedyaṃ vidurbudhāḥ ||
Jyotiścakraṃ tu lokasya sarvasyoktaṃ śubhāśubham |
Jyotirjñānam ca yo vetti sa vetti paramāṃ gatim ||
Tadbhāvabhāvinaṃ nityam taṃ devā brāhmaṇaṃ viduḥ |
Tasmātpūrvamadhīyīta jyotirjñānaṃ dvijottamāḥ ||
Dharmasūtraṃ tathā paścādyajñakarmavidhikriyāḥ |
Tasmāt puṇyaṃ samaṃ vedairyajñacakṣuḥ sanātanam |
Svargyamadhyeyamavyagrairbrāhmaṇaiḥ saṃśritavrataiḥ |
(ii) Na sāmvatsarapāṭhī ca narakeṣūpapadyate |
Brahmalokapratiṣṭhāṃ ca labhate daivacintakaḥ ||
Gaṇayati yaḥ pratikūlān grahān yathāsthānasaṃśṛtānnityam |
Tasyānukūlaphaladā bhavanti te naiva kurvate neṣṭam ||

[1]The verses quoted are: Ā, i. 6c; 7; ii. 9 (c-d), 15, 17 (a-b), 28; iii. 12, 13, 14, 15, 17, 18, 19, 20, 21, 25; iv. 1, 6, 10, 12, 15, 18, 19, 24, 27, 37, 38, 40.

[2]The verses quoted are: PSi, i.4 (with pauliśa iti sphuṭo' sau); xiii. 2, 3, 10; and BṛSaṃ, i. 9; iii. 1, 2; xvii. 2, 3.

[3]The verses quoted are: MBh, v. 33, 34, 35; vi. 52, 53; LBh, i. 4, 5, 6, 7, 8, 9, 10, 11, 14, 17, 19, 20, 21, 29, 30; ii. 6, 7, 8, 16, 20, 21; iii. 5, 6, 17, 18, 19, 20; iv. 2, 3, 4, 5, 7, 11, 12, 14; vii. 2 (c-d). The following verses from Bhāskara I's com. on Ā, iii. 5 is also quoted:

Vasudevādisārpārdhādayanaṃ munayo jaguḥ |
Mṛgakaryādito dṛṣṭaṃ kathaṃ taddhi gatervinā ||

[4]The verses quoted are: BrSpSi, i. 15, 17 (a-b), 18 (a-b); ii. 1, 42 (c-d), 43, 44, 61, 65, 66; iii. 34, 35; iv. 5; v. 1 (a-b); vi. 1, 2, 3, 4; ix. 1; x. 35; xii. 11 (a-b); xiv. 23, 33, 36, 38, 39, 40, 41, 42, 43; xxi. 1, 2, 3, 4, 5, 6, 7, 8, 9, 15 (a-b), 27, 28; and KK (Pūrva), i. 16, 17 (with candramasaḥ saptanagāḥ in place of śaśinaḥ saptakamunayo; ii. 6 (a-b); iii. 5 (a-b), 6; viii. 1 and the verse

Dve tisro'rdhacatasraḥ kalāścatasro dalādhike dve ca |
Sphuṭamānakalā guṇitā vyāsārdhena svakarṇahṛtāḥ ||

which Bhaṭṭotpala comments but Bina Chatterjee excludes from the text. Also KK (Uttara), i. 5; ii. 1 (a-b); v. 2

[5]The verses quoted is GCN, i. 10.

[6]The verses quoted are:

Divāgaṇādviśvahatāt pṛthaksthitāddivāgaṇonādvasuṣaṭkabhājitāt |
Phalānvitādvā himaguprasiddhaye kṣipenmṛgāṅkadhruvake'ṃśakādikam ||
(Cf. ŚiDVṛ, i. 33 (f.n.)

Ravirdvibhakto ravirāhato nṛpaiśśarābhrabāṇairvihṛtaḥ kujo'thavā |
Ravirnagaghnartuyugoddhṛtaścaturhatārkayukto bhavatīndujo'thavā |
Ravirvibhakto ravibhī ravirhṛto radābhracandrairathavā gururbhavet |
Ravirdaśaghnādṛtubhirhṛtassitaḥ punastato rāmajināptavarjitaḥ |
Ravī rasaghno'yutabhājito bhaveddhṛto raviḥ khāgnibhirarkajo'thavā |
Nakhoddhṛto bhāskara iṣvṛtudvikairhṛto'thavā candraripurvilomagaḥ |
(Cf. ŚiDVṛ, i. 39 (f.n.)

Natonanighnā khayamā vibhaktā dvighnākṣakarṇena vilambanādyaḥ |
This last hemistitch does not occur in ŚiDVṛ.
Also, ŚiDVṛ, i. 40; ii. 17, 18, 19; v. 11, 29 (with pūrvasyāṃ syāt in place of pūrvāśāyāṃ); viii. 1, 2, 3, 4; ix. 1, 2, 3, 4, 5, 6, 9, 10; xii. 1, 2, 4.

[7]The verses quoted are: PG, Rules 24 (c-d), 32 (a-b), 33 (c-d), 41,43.

Bhaṭṭotpala[1], Śrīpati[2] and also from Sūryadeva Yajvā's own work[3] which he calls "asmadīyagrantha". Some ancient authors are also quoted anonymously.[4]

The following verse which really belongs to the Siddhāntaāekhara of Śrīpati has been wrongly ascribed to Varāhamihira:

Grahanakṣatradharitrīsaṃsthānasyeha darśanopāyaḥ ।
Gola iha kathyate'sau kṣetraviśeṣo gaṇitagamyaḥ ॥

Similarly, the following verse whichBhattotpala[5] has ascribed to Viṣṇucandra has been ascribed by Sūryadeva Yajvā to Varāhamihira:

Divasakareṇāstamayaḥ samāgamaḥ śītaraśmisahitānām ।
Bhaumādīnāṃ yuddhaṃ nigadyate'nyonyayuktānām ॥

But this verse occurs neither in Varāhamihira's Bṛhat-saṁhitā nor in his Pañca-siddhāntikā.

The commentary gives the following information regarding the commentator Sūryadeva Yajvā:

1. That he was a Brāhmaṇa of Nidhruva Gotra.[6] On the basis of this Gotra, K.V.

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[1]The passage quoted is:

Agavasuśaraśakakālāntara etc. (10 lines)

giving Bhaṭṭotpala's Bīja for Khaṇḍakhādyaka. For full passage see KK, vol. I, pp. 162-163 (Bina Chatterjee's ed.).

In this connection the traditional Bīja corrections of the Āryabhaṭa school viz. candre bāṇakarā etc. and vāgbhāvonā etc. as well as Lala's Bīja, śāke nakhābdhirahite etc., are also quoted.

[2]The verses quoted are: SiŚe, i. 3-5; vi. 1; viii. 1-10; ix. 4, 6, 7; xii. 2-4, 11, 12, 14, 16; xiv. 5, 6; xv. 30.

[3] The verses quoted are:

Vikṣepaṃ palabhānighnamarkāptaṃ trijyayā hatam ।
Dyuvyāsārdhahṛtaṃ triṃśadguṇitaṃ dviṣṭhamekataḥ ॥
Tat svadeśodayaprāṇiranyatassaptamāsubhiḥ ।
Hṛtvāptaphalamaṃśādi grahe kṣepavaśāddhanam ॥

[4] The following verses are ascribed to them:

(1) Māso'ṅgotsavasyeti viśodhya kalivāsarāt ।
Sāmagaghnaṃ dhruvādabdaṃ saṃśodhya dyugaṇo bhavet ॥

(2) Bhājakādguṇakāreṇa nihatādyena kenacit ।
Bhājako guṇahārādvā bhājakenāpyate guṇaḥ ॥
Matirbhavati sā saṅkhyā hartavyo hanyate yayā ।
Matiranyatvamāpnoti phalataḥ khaṇḍanaṃ prati ॥
Hīnāṃśe'ṃśaḥ phale śeṣo'dhikāṃśe tvadhiko bhavet ।
Chedo hārahato hāro guṇahārau ca tau dṛḍhau ॥
Tābhyāmāptaṃ phalaṃ hāre pūrvalabdhādṛṇaṃ dhanam ।
Vyatyayād guṇakāre tu guṇyamekamihocyate ॥

These verses occur also in the Prayoga-racanā, an anonymous commentary on the Mahābhāskarīya of Bhāskara I.

(3) Vibhaktayorvā guṇahārayoḥ syāt pravṛddhayorveṣṭatamena rāśinā ।
Ekena hatvā hṛtayoḥ pareṇa vā viparyaye vā na phale viśeṣaḥ ॥

(4) Tanmadhyalagnotthacarādrasaghnāt palaprabhāptena ca saṃskṛtācca ।
Palaprabhonāhatapūrṇabāṇād dvighnāttathā tattvahṛtā natiḥ syāt ॥

[5]See his com. on KK (Pūrva), ch. viii, opening lines.

[6]This is mentioned in the colophons occurring at the ends of the first and second chapters.

Sarma concludes that he was a Brāhmana of the Baudhāyana-sūtra whose Pravara Ṛṣis were Kaśyapa, Avatsara and Naidhruva.[1]

2. That he was born on Monday, the 3rd tithi of the dark half of Māgha, Śaka 1113, the Kali Ahargaṇa for that day, according to the Āryabhaṭa-siddhānta, being 15,68,004.[2] This corresponds to Monday, February 3, A.D. 1192. The Sun was then in Aquarius (Kumbha) and the Moon in Corvus (Hasta).

3. That he belonged to the Cola country (which roughly comprised of Tanjore and Trichinopoly districts of Tamil Nadu) and was resident of the town called by the names Gaṅgāpura, Gaṅgāpurī and Śrīraṅga-gaṅgāpurī which may be easily identified with Gangaī-koṇḍa-Colapuram (lat. 11°13′ N.; long. 79°30′E.) situated about 64 km. north of Tanjore. For, according to Sūryadeva Yajvā, the equinoctial midday shadow at that place was $2\frac{2}{5}$aṅgulas which corresponds to the latitude 11°.3 N. This is also substantiated by the ascensional differences and times of rising of the zodiacal signs stated by Sūryadeva Yajvā for the said place. Gaṅgāpurī has been stated to be 11 yojanas east of Kharanagara (modern Karur), a place supposed to be on the Hindu prime meridian.

4. That he had performed the Vedic Soma sacrifice. Likewise he bore the surnames Somasut[3] or Somayāji or simply Yajvā, and Somaūri or simply Sūri. It is these surnames by which he has called himself in his works.

Towards the end of the commentary, Sūryadeva Yajvā lists the works written by him in the following chronological order:

1. Comments on Govinda Svāmī's Bhāṣya on the Mahābhāskarīya or Bhāskara I.

2. Commentary on the Āryabhaṭīya of Āryabhaṭa I. This has been edited by K.V. Sarma and published by Indian National Science Academy, New Delhi, in 1976.

3. Commentary on the Mahāyātrā (also called Bṛhadyātrā) of Varāhamihira.

4. Commentary on the Laghumānasa.

5. Commentary on the Jātakapaddhati of Śrīpati.

Sūryadeva Yajvā's commentary on the Laghumānasa gives epochal constants for Thursday noon, Caitrādi, Śaka 1170 (corresponding to Thursday, February 27, A.D.

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[1]See K.V. Sarma's edition of the Āryabhaṭīya with the commentary of Sūryadeva Yajvā, introduction, p. xxvi.

[2]Sūryadeva Yajvā writes: Viśveśa 1113 mite śāke māghakṛṣṇatṛtīyāyāṃ somavāre ācāryāryabhaṭasiddhāntasiddho'smajjanmadine'hargaṇaḥ 15,68,004.

[3]Some karmaṇyupapade bhūte sunāteḥ kvip. Tena somasut iti siddham. See Pāṇini, 3.2.90.

1248) and was likewise written about that date. Sūryadeva Yajvā was then about 56 years old.

From the remarks made towards the end of the last-named commentary, we learn that he intended to write a commentary on the Khaṇḍakhādyaka of Brahmagupta but we do not know whether he actually wrote it.

5.13. Parameśvara's commentary

Parameśvara's commentary on the Laghumānasa was edited by B.D. Apte and published in Ānandāśrama Sanskrit Series (No. 123), Poona, in A.D. 1944. We have designed it as C.

This commentary is called Mānasa-vyākhyāna and explains the text so as to make its meaning clear. In order to make the computations simpler the initial constants are given for Sunday noon, Caitrādi, Saka 1331 (i.e., Sunday noon, March 17, A.D. 1409), this being the time about which the commentary was written.

The commentator Parameśvara is the well known Kerala astronomer who wrote a large number of works. He was a Ṛgvedin of Āśvalāyana-sūtra and Bhṛgu Gotra, and lived in the village Aśvattha (identified with modern Ālattūr) situated on the north bank of the river Nīḷā (Mal. Bhāratappuzha) near the Arabian sea-shore. This village was situated, according to the present commentary, at a distance of 18 yojanas towards the west of the Hindu prime meridian, the equinoctial midday shadow there being 2 aṅgulas 18 vyaṅgulas, and the hypotenuse of the equinoctial midday shadow 12 aṅgulas 13 vyaṅgulas. Likewise the latitude of the place was 10°50′N.

Parameśvara was a prolific writer and wrote a large number of works, of which mention may be made of the following:

1-8. The eight Dīpikās, viz. Muhūrta-dīpikā, Siddhānta-dīpikā, Aṣṭāṅgahṛdayavyākhyā Vākyapradīpikā[1], Bhā-dipikā (untraced so far), Nyāya-dīpikā (or Grahaṇanyāya-dīpika), Karmadīpikā, Gola-dīpikā,[2] and Bhaṭa-dīpikā.
9. Dṛggaṇita.
10. Grahaṇa-maṇḍana.
11. Grahaṇāṣṭaka.
12. Vākya-karaṇa.
13. Muhūrtāṣṭaka[3] (on astrology).

He also wrote commentaries (vyākhyā) on the following works:

Āryabhaṭīya, Mahābhāskarīya, Mahābhāskarīya-bhāṣya of Govinda Svāmī,

[1] The Aṣṭāṅgahṛdaya of Vāgbhaṭa is a famous work on Āyurveda, and this is a commentary on that work.
[2] There are three versions of this work.
[3] There are two versions of this work.

Laghubhāskarīya, Sūrya-siddhānta, Laghumānasa, Līlāvatī, Goladīpikā, Vyatīpātāṣṭaka, Jātakakarmapaddhati (of Śrīpati), Praśnaṣaṭpañcāśikā (of Pṛthūyaśas), Muhūrtāṣṭaka, the last four works being on astrology. The commentary on the Āryabhaṭīya bears the name Bhaṭadīpikā and that on the Mahābhāskarīya Karmadīpikā.

5.14. Yallaya's commentary[1]

Five manuscripts of this commentary are available to us, three exist in the Government Oriental Manuscripts Library, Madras, one in the Government Oriental Library, Mysore, and one in the Sampurnanand Sanskrit University Library, Varanasi:

1. Madras: Ms. No. R 7705. Ff. 16-44v. Incomplete.
2. Madras: Ms. No. D 13475. 63 ff. Telugu. Incomplete. (Breaks off in the midst of Tripraśnādhikāra).
3. Madras: Ms. No. D 13476. Ff. 1-16. Telugu. Incomplete.
4. Mysore: Ms. No. B 580. 107 ff. Complete but some portion in the beginning missing.
5. Varanasi: Serial No. 37292. Ff. 2-29. Incomplete. Contains com. on chap. 1; some portion towards the beginning and some portion towards the end of chap. 2; com. on the first three verses of chap. 3, that on vs. 3 incomplete. The portion towards the beginning which is missing in the previous manuscript occurs in this manuscript.

A transcript in Devanāgarī characters of the Mysore manuscript (B 580) exists in the Lucknow University Library, Lucknow. Its accession no. is 404188. We have designated it as D_1. It begins and ends thus:

Beginning:

Śrī gaṇādhipataye namaḥ. Śrīśāradāgurubhyo namaḥ.

Atha laghumānasagrantho vyākhyāyate vākyairgranthaiśca. Iha śāstre kāni sambandhābhidheyādhikāriprayojanānīti ceducyante. Vācyavācakabhāvaḥ sambandhaḥ. Vācyo'rthaḥ, vācakaḥ śabdaḥ. Kaṭapayādi lakṣaṇaḥ. Tadupāyopeyātmalakṣaṇa evātra sambandhaḥ. Upāyastvetacchāstram. Atroktārtha upeyasañjñiko bhavati. Tathā ca ābrahmādivinissṛtaṃ vedāṅgamiti sambandhaḥ. Grahāṇāṃ madhyasphuṭagatyupakaraṇagrahaṇagrahayutyudayāstamayacandracchāyāśṛṅgonnatipāta-vaidhṛtyādividhyātmako viṣayaḥ. Sa ca grahadhiṣṇyānāṃ cāravicāro bhavati. Tadadhikārī tu vedāṅgatvād vipra eva nānyaḥ. Asya taccāramūlakāraṇavijñānāt ihaparaloka-

[1]Yallay. is sometimes spelt as Yellaya or Ellaya.

sukhāvāptirbhavatīti yattat prayojanamiti vijñāyate. Atra [sadbhiḥ] satāmayamācāraḥ yacchāstraprārambheṣvabhīṣṭadevatāprasādāttannamaskāreṇa tatstutyā vā tatsmaraṇena vā tadbhaktiviśeṣeṇa vā'bhipretārthasiddhiṃ vāñchanti. Tadayamapi mañjulācāryo nāma dvijottamo' rkaprasādena jyotiśśāstrasaṅgrahadṛggaṇitaṃ cikīrṣuraśeṣavighnopaśāntaye bhagavantamādityaṃ gopitasvanāmavikhyāpakavyājena stuvan svanāmagotrapaṭṭanagranthanāmādyaślokena nibadhnāti —

Prakāśādityavatkhyāto bhāradvājo dvijottamaḥ I
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam II 1 II

End:

Athācāryo granthasamāptiṃ kurvan pratikañcukānuddiśya ślokamāha —

Mānasākhyagrahajñānaṃ ślokaṣaṣṭyā mayā kṛtam I
Bhavantyapayaśobhājaḥ pratikañcukakāriṇaḥ II

Śramaṃ vinā manasā'pi sādhyatvānmānasaṃ nāma grahagatijñanasādhanaṃ karanaṃ anuṣṭupślokānāṃ ṣaṣṭyā kṛtam. Sūryādibhirbahugranthairuktaṃ yāvadgrahagaṇitamalpagranthenaiva mayoktamiti bhāvaḥ. Evaṃ ślokaṣaṣṭyaiva sarvagaṇitaśāstraṃ saṇkṣipyetarānapekṣaṃ spaṣṭārthaṃ dṛksiddhamalpagaṇitasādhyaṃ mayā kṛtamimaṃ granthaṃ pratipattumicchanti te pratikañcukakāriṇaḥ apakīrtibhājo bhavantīti. Vartamānatvāt sarvakāloktiḥ. Anenaitacchāstraṃ sacchiṣyāya bahudhā vicārya upadeṣṭavyamiti gamyate. Anyathā pratikañcukā bhavanti. Pratikañcukakṛiyārhaśiṣyavidyāpradāne doṣo'sti. Tatroktaṃ śrīpatiprabhṛibhiḥ —

Pratikañcukakṛtkṛtaghnavidvadvitpatitādhārmikamūrkhadurjanebhyaḥ I
Grahatantrarahasyamapradeyaṃ dadataḥ syāt sukṛtāyuṣoḥ praṇāśaḥ II

Colophon:

Śrīmacchambhuvaraprasādavilasadvāgarthavān yallayaḥ
Śrīmacchrīdharanandanassuruguruprakhyādgurossūryataḥ I
Samprāptāgamakovido'sti racitā śṛṅgonnateḥ prasphuṭaṃ
Ṭīkā kalpalatā ca tena hi mayā śrīmānase vistṛitā II

Iti śrīmaccandraśekharavaralabdhavāgvibhavena śrīśrīdharācāryaputreṇa śrībālādityasutasūryācāryaśiṣyeṇa yallayākhyena kṛtāyāṃ śrīmañjulācāryakṛtalaghumānasakaraṇavyākhyāyāṃ kalpalatākhyāyāṃ candraśṛṅgonnatyadhikāro'ṣṭamo'dhyāyaḥ. Śrīḥ. Śrīḥ.

Post-colophon:

Śrī jagadgurucaraṇāravindārpaṇamastu.

Laghumānasṭīkā'sau yallayākhyena dhīmatā ।
Kṛtā lokopakārāya ślokānāṃ dvisahasrataḥ ॥
Samāpto'yaṃ granthaḥ.

A transcript in Devanāgarī characters of the Varanasi manuscript exists in A.N. Singh Collection (No. 29) in thē Department of Mathematics and Astronomy, Lucknow University. We have designated it as D_2. It begins and ends thus:

Beginning:

Śrīḥ. Śrīgaṇeśāya namaḥ.

Śrīmadgrahanakṣatrairanumitikālassa nirguṇo devaḥ ।
Gaṇadevo gaurīśo madvāgarthaprabodhako bhavatu ॥ 1 ॥
Śrīvīreśaśśarabheśaḥ sakalān vighnān nirasya vāgarthān ।
Dadyādasmākaṃ yo taṃ vande'haṃ gaṇeśvaraṃ sūryam ॥ 2 ॥
Laghumānasākhyagaṇitaskandhasya tu yallayābhidhaḥ kurute ।
Ṭīkāṃ sūryagurostaccaraṇadvandvaṃ praṇamya medhāvī ॥ 3 ॥
Saurādikasiddhāntānāryabhaṭabrahmaguptādyaiḥ ।
Kṛtatantrāṇi ca dṛṣṭvā mānasamuktaṃ ca mañjulācāryeṇa ॥ 4 ॥
Tatkṛtapūrvadhruvakān dṛṣṭvā taddhetutantrāṇi ।
Jñātvā tadbhagaṇādīn vakṣye pūrvadhruvān grahādīnām ॥ 5 ॥

End:

Lagnānayane tatkālānayane ca maduktāryāḥ saṃlikhyante —

Ayanāṃśasaṃskṛtaraverbhogyāṃśaistadgatodayaprāṇāḥ ।
Hatvā khāgnibhirāptānasūn tyajediṣṭanādikāsubhyaḥ ॥

....

Yadi bhuktaṃ bhogyaṃ vā sveṣṭāt saṃśodhituṃ na sakyaṃ śyāt ॥
Iṣṭavighaṭikāstriṃśadguṇitāstadrāśimānena ।
Bhaktvā (The ms. breaks off here)

The two manuscripts exhibit significant reaaing — differences and seem to be based on different archetypes.

An incomplete manuscript breaking off four lines before the end of the commentary on the last verse of chapter four belongs to Dr. S.D. Sharma, Professor of Physics, Punjabi University, Patiala (Punjab). It begins and ends as follows:

Beginning:

Mānasasīddhāntaḥ
Śrī Veṅkaṭeśāya namaḥ.

Śrīveṇkaṭādrinilayakamalākāmukaḥ pumān ।
Abhaṅguravibhūtiste taraṅgayatu maṅgalam ॥
Śrīmadgrahanakṣatrairanumitakālassa nirguṇo devaḥ ।
Gaṇadevo gaurīśo madvāgarthaprabodhako bhavatu ॥

End:

Pūrvāvadānītacandrabimbavyāsakalāḥ 30।48 gurormadhyabimbapramāṇam 200. Etaddaśaghnapramāṇam daśaghnasaṃkhyāsaṃyuktaguruśīghracchedenānena 41।8 vibhajya gurusphuṭabimbavyāsakalāḥ 4।52 mānārdhayogaḥ [17।50] etatpūrvasaṃpāditabimbāntarāt tyaktvā śeṣaṃ 226।56 tayorgra (The ms. breaks off here)

Yallaya's commentary, Laghumānasavyākyā, has been given a special name Kalpavallī. It is a vyākhyā of a special type. It explains the text, gives rationale of the rules where necessary, and in the end briefly summarizes his commentary in verse. Towards the ends of the chapters it fully illustrates the working of the rules by solving actual astronomical problems.

The commentator quotes from a large number of anterior works in support of his statements or arguments which bear evidence of his wide reading and sound scholarship and throw light on the works which were popular in the area in which he lived. Amongst the works quoted are the Vedāṅga-jyotiṣa[1] of Lagadha, the Āryabhaṭīya[2] of Āryabhaṭa I, the Sūrya-siddhānta[3], the Brahmasiddānta[4], the Vṛddhavasiṣṭha-siddhānta[5], the Bṛhat-saṃhitā[6] of Varāhamihira, the Vaṭeśvara-siddhānta[7] of Vaṭeśvara, the Siddhānta-śekhara[8] and the Śrīpati-paddhati[9] of Śrīpati,

[1]The verse quoted is: VJ (Ārca), vs. 36 or VJ (Yājuṣa), vs. 3.

[2]The verses quoted are: Ā, ii. 9c, 10; iv. 2, 14, and 31.

[3]The verses quoted are: SūSi, i. 59 (a-b), 66 (a-b), 67; ii. 34-37, 53-54; iii. 50; iv. 6, 9, 10-11, 18, 19-20, 22-23, 26, and 37; vi. 24; vii. 17, 18-24; ix. 2-3, 4; x. 1; xi. 8 (c-d), 19; xii. 29-31, 68-69

[4]The verses quoted are: BrSi, ii. 82; v. 39 (c-d)-40 (a-b), 40 (c-d)-41 (a-b).

[5]The verses quoted are:

Asitacaturdaśyānte pratimāsaṃ cāstameti śītāṃśuḥ ।
Satataṃ darśasyānte tulyau rāśyādibhirniyatam ॥
Vikalaḥ pratipadyante'bhyudayaṃ yāti prabhākarāttyaktaḥ ।
Dvādaśa bhāgavṛddhyā tithayaścāndrāśca saṃbhūtāḥ ॥

But these verses are not found to occur in the Vṛiddhavasiṣṭha-siddhānta edited by Vindhyeśvarī Prasāda Dvivedī.

[6]The verses quoted are: BṛSaṃ, xvii. 2-3.

[7]The verses quoted are the same as quotations 8 and 9 given above under Praśastidhara's commentary. See supra, p. 29 (foot-note). As already stated they are not found to occur in the Vaṭeśvara-siddhānta available to us. It seems that there was another version of the Vaṭeśvara-siddhānta which was popular in Āndhra Pradeśa.

[8]The verses quoted are: SiSe, i. 5; xx. 28.

[9]The verses quoted are:

Madhyāhnāṃśumatoryadeva vivaraṃ kālassa ukto nataḥ
so'pyabhrāgniparicyuto raviniśāmadhyāntare connataḥ ।
Madhyāhnātpatite tu vāsaragate syāt prākkapāle nataṃ
yāte'hni dyudalonite punaridaṃ pratyakkapāle natam ॥

the Daivajñabhūsana[1], Daivajñābharaṇa[2] and Gaṇakānanda [3] of his teacher Sūryācārya, and from the anonymous works of Mallinātha[4], Mallikārjuna[5] and his own[6].

Rātryāśśeṣe gate vā bhavati hi samaye janma cettadghaṭībhiḥ
saṃyuktaṃ vāsarārdhaṃ natamiti gaditaṃ pūrvat prāk ca paścāt I
Tasmādevaṃ sphuṭārkāduditakaraṇataḥ svodayairiṣṭakālā-
tkuryāllagnaṃ saṣaḍbhaṃ tadiha sugaṇakairastalagnaṃ niruktam II
Laṅkodayaiḥ pūrvanatād ṛṇākhyaṃ
pratyaṅnatād yacca bhavet dhanākhyam I
Lagnaṃ taduktaṃ khalu madhyasañjñaṃ
ṣaḍbhānvitaṃ tacca rasātalākhyam II

[1]The verse quoted is:
Indagapamāśakāḥ svapalabhāgahīnā sadā
tadā svasamamaṇḍalam viśati tigmakaramaṇḍalam I
Tribhāgayutasāyakāṅgulamitākṣabhā yatra sā
kadācidapi nordhvagatassa tadudaksthitānāṃ raviḥ II

[2]The verses quoted are:
Trilokīpradīpād vidhoḥ bhārdhasaṃsthād
dineśānmahīvṛttaśaṅkoḥ prabhāyām I
Praviṣṭe vidhau parvaṇīha prasiddham
vṛthā rāhuṇā grastamityuktamādyaiḥ II
Laṅkāyāṃ na tu rāmasetunikaṭe saptāṃśako'rkagrahaḥ
śrīśaile daśaliptikā vasukalā śrīkālahastīpure I
Tatrāvantipure'rdhamardhamanalāṃśonaṃ tu kedārake
tasyāsau grahaṇasya heturiti cet svarbhānavaste kati II

[3]The verses quoted form chap. 5 of the Gaṇakānanda and relate to the diagram of the eclipses (grahaṇaparilekha).

[4]The verse quoted is:
Pūrvāhṇe'hardale hīne nate gataghaṭī bhavet I
Aparāhṇe nate yukte'hardale gatanāḍikāḥ II

[5]The verses quoted are:
(1) Gataiṣyakhaṇḍayogārdhamantarārdhena saṅguṇāt I
Bhāgādeḥ khāgnilabdhonaṃ bhogyajyā mānase sphutā II
(2) Chedā jināśvino'gāṅkā ravīndvoḥ sphuṭakarmaṇi I
Gatisphuṭārthamarkendvośchedau tāveva mānase II
Dviguṇasphuṭaliptighnabhujākoṭilavādikaḥ I
Ṣaṣṭyuddhṛtādhaḥ prakṣepe doḥkoṭijyā lavādikāḥ II
Koṭyardhasaṃskṛtau chedau ravīndvorbimbasādhane I

[6]The verses quoted are:
Ayanāṃśasaṃskṛtaraverbhogyāṃśāṃstadgatodayaprāṇaiḥ I
Hatvā khāgnibhirāptānasūṃstyajediṣṭanādikāsubhyaḥ II
Saṃyojya ravau bhogyaṃ śeṣāsubhyaḥ parodayaprāṇān I
Tyaktvā śodhital gnapramitaṃ rāśau raveryuñjyāt II
Śeṣaṃ triṃśadguṇitaṃ śuddhoparilagnamānabhaktaṃ cet I
Labdhāṃśādīn bhānau yuñjyāt tatsāyanaṃ lagnam II
Kevalasāyanasūryāllagnaṃ kuryād divā niśāyām tu I
Ṣaḍrāśiyutādbhānoreṣyaṃ lagnaṃ kramāt sādhyam II
....
....
Hīnaikyabhāgajāsūn adhikasya ca bhuktabhāgajātāsūn I
Saṃyojyāntararāśyāsumānaṃ ca tayossa madhyakālaḥ syāt II
Udaye kṣitije lagnaṃ madhyāhne madhyalagnaṃ syāt I
Bhānuścakrārdhayuto niśāmukhe tadbhavellagnam II

The sources of the following verses quoted in the commentary could not be traced so far:

1. Jīvāssāṅghryabdhisārdhāgnidvyaṃśā liptāstu tāḥ sphuṭāḥ ।
Bhuktārdhāṃśonitabhuktāṃśabhuktāṃśadviguṇonitāḥ ॥
Dviguṇasphuṭaliptighnabhujākoṭilavāditaḥ ।
Ṣaṣṭyudhṛtādhaḥ prakṣepe doḥkoṭijyālavādikāḥ ॥ [1]
2. Vṛttasya ṣaṇṇavatyaṃśaṃ samajyā sā'bhidhīyate ।
3. Kudalakṛtiṃ karṇakṛteḥ projhya padaṃ dvitriguṇasamalambam ।
4. Bhānoḥ phalakalābhāṃśaliptāścandre raveriva/[2]
5. Lambanadyugatāt pañcadaśabhirnatasādhanam ।
Yasmin kapāle parvānto dṛśyate lambanaṃ ca tat ॥ [3]
6. Dinārdhena nataṃ sādhyaṃ lambanasphuṭaparvaṇaḥ ॥
Natanāḍyādayaḥ ṣaḍbhīḥ guṇitā aṃśakādayaḥ ॥
7. Āryabhaṭīyāt samuditadhruvake tu mānase nityam ।
Sāyanārkād dvādaśabhāgān tyaktvā caraṃ sādhyam ॥
8. Atha dṛksaṃskāravidhiḥ —
Kalyādigatavarṣāṇi ṣaṣṭikṛtyā vibhājayet ।
Śeṣaṃ yathā chedadalādalpaṃ bhavati tattathā ॥
Rāhuśukrejyacandrāṇāṃ kramācchesaṃ kṛteṣubhiḥ ।
Gajabhūpairvasukṛtaiḥ śivairhatvā khakheṣubhiḥ ॥
Vibhajya labdhā liptādiphalānyeṣu viśodhayet ।
Śanau bhāgatrayaṃ yuñjyāt yadi sidhyanti dṛksamāḥ ॥

and

Kalyabdān khakharasaguṇairbhājayeccheṣasaṃkhyāṃ
Jñātvā śeṣaṃ khakhagajakutaḥ svalpasaṃkhyā yadi syāt ।
Tatsyāt tasmādadhikamiti cet ṣaṣṭikṛtyantaraṃ tat
Śeṣaṃ prājñaḥ khacaraguṇakaistāḍayed vakṣyamāṇaiḥ ॥
Candroccasya śivā 11 gurordinakarāḥ 12 śukrasya netrābdhayaḥ 42 ।
Śītāṃśorgiriśā 11 bhavanti guṇakā dṛksāmyasiddhyai sphuṭāḥ ।
Pañcārkāḥ 125 pavanāśvisītarucaya 125 stattvendava 125 śchedakāḥ
Vyomābhrendriya 500 sammitāśca kalikāstyājyāḥ khageṣṭāgatāḥ ॥
Adrikarā 27 hataśeṣaṃ khapañcadasrai 250 rvibhājayed rāhoḥ ।
Talliptādyarāhau viśodhayet tena vikṣepaḥ ॥[4]
9. Yāmyottarakṣepavaśāt sudhāṃśoḥ
Sparśo girīśāgnidiśo ravestu ।
Kravyādavāyyoḥ kramaśo'tha mokṣo
Vāyvindraśatrvoranaleśayośca ॥

[1]These verses occur as part of the text in Ms. A containing the text of the Laghumānasa along with Praśastidhara's commentary but as Praśastidhara has not commented upon them they seem to be interpolatory there. Yallaya has quoted them and explained them also.
[2]This hemistitch occurs in Mss. H_1 and H_2 also.
[3]Yallaya has ascribed this verse to his teacher Sūryācārya.
[4]The Bīja corrections stated in these verses are quite different from the traditional Bījas of the Āryabhaṭa school. They are also different from those given by Brahmagupta, Lalla and Bhaṭṭotpala.

10. Bhagatādabhrādbhi 40 guṇād guṇā 3 ptamaṃśādiko graho bhavati |
Aṃśādeśca triguṇāt khābdhi 40 vibhaktād bhaved bhagatam ||
11. Syāt pāto harṣaṇārdhāt prāk paścād yogacatuṣṭaye |
Svarṇākhyeṣvayanāṃśeṣu vaidhṛtyantācca vaidhṛtaḥ ||

From the two verses[1] occurring towards the end of Yallaya's commentary on the Sūrya-siddhānta, we learn that:

(1) Yallays belonged to Kāśyapa Gotra and his genealogy was as follows:

Kalpa Yajvā (great grand-father)
|
Yallaya (grand-father)
|
Śrīdhara (father)
|
Yallaya (commentator)

His father Śrīdhara (whom he calls Śrīdharārya and Śrīdharācārya also) was a good reciter of hymns in praise of gods. He was indeed different from his namesake, the author of the Pāṭīgaṇita and the Triśatikā.

(2) He received his education, particularly in astronomy, from Sūryācārya, the son of Bālāditya. He speaks highly of him and compares him with Bṛhaspati, the Guru of the gods, and quotes from three of his works, viz.

(i) Gaṇakānanda. A manuscript of this work exists in the Government Oriental Manuscripts Library, Madras, and a transcript of it in our collection. This work is in eight chapters, and the date of its composition is A.D. 1460.

(ii) Daivajñābharaṇa. This work was probably a Tantra. Yallaya says: "The Golādhyāya of the Sūrya-siddhānta being brief, my teacher, who was proficient in all the Siddhāntas, wrote a Tantra called Daivajñābharaṇa."[2]

(iii) Daivajñabhūṣaṇa.

(3) He was resident of a small town (paṭṭaṇa) which was situated to the north of

Addaṅkyāḥ saumyabhāge sakalaśubhakaraḥ kalpapūrvābhidhānaḥ
tasmin yajvā prasiddhassakalaguṇayaśāḥ tatsuto yellayākhyaḥ |
Tatputraśśrīdharākhyaḥ stutipaṭhanapaṭustatsuto yellayākhyaḥ
śrīsūryādāptavidyaḥ śivanihitamanāḥ kāśyapo'sti prasiddhaḥ ||
Śrībālādityaputrāt suragurusadṛśāt sūryataḥ prāptavidyo
vidvān śrīyellayākhyaḥ prathitaguṇayaśāḥ śrīdharāryasya putraḥ |
Siddhāntasyārkanāmno viśadapadavatīm pañcikāṃ kalpavallīṃ
mānādhyāyasya samyak suragurukṛpayā proktavān śaṅkarāya ||
[2]See Yallaya's com. on SūSi, xii. 36.

Addankī (lat, 15°.49 N.; 80°.01 E.) in Andhra Pradeśa. This town lay towards the south-east of Śrīśaila and was called Skandasomeśvara. Yallaya says: "My native place is Skandasomeśvara-paṭṭaṇa which is located towards the south-east of Śrīśaila."[1]

The Rsine of colatitude (R = 3438′) for this town has been stated to be 3313′44″.[2] This town was therefore situated in latitude 15°33′N., approximately. The distance of this town from the Hindu prime meridian has been stated to be 36 yojanas towards the east of it, the circumference of the local circle of latitude being 4877 yojanas. The longitude of the town was therefore about 78°21′ east of Greenwich.

From Yallaya's commentary on the Sūrya-siddhānta we further learn that his maternal grandfather, who was known as Yellaya Saiddhāntika, lived at Vidyānagara (modern Vijayanagara), and his commentary on the Sūrya-siddhānta was written while he was living at Vidyānagara and coaching the son of Vīrabhadra, the son of Yellaya Saiddhāntika.

Towards the beginning of his commentary on the Laghumānasa, Yallaya gives the initial constants for Tuesday noon, Caitrādi, Śaka 1404 (corresponding to Tuesday noon, March 18, A.D. 1482), which shows that he must have started writing this commentary about that date.[3] His commentary on the Sūrya-siddhānta was written in A.D. 1472 and that on the Āryabhaṭīya in A.D. 1480.

5.15. Bhūdhara's commentary

A manuscript containing an incomplete and anonymous commentary on the Laghumānasa exists in the Sampurnanand Sanskrit University Library, Varanasi. Its serial no. is 36944 and accession No. 2970. A xerox of this manuscript belongs to our collection. We have designated it as E.

This commentary starts from the very beginning and runs up to verse 27 of the Tripraśnādhikāra where it breaks off. It begins and ends as follows:

Title: Atha sodāharaṇalaghumānasārambhaḥ.

[1]See Yallaya's com. on SūSi, i. 57 (c-d)-58.

[2] The equinoctial midday shadow of this town has been stated to be 3 aṅgulas 20 vyaṅgulas and the hypotenuse of the equinoctial midday shadow, 12 aṅgulas 28 vyaṅgulas.

[3]Other dates mentioned in the commentary are:

(1) Saturday, Phālguna Pūrṇimā, Śaka 1407 (i.e., Saturday, February 18, A.D. 1486), when a lunar eclipse occurred at Skandasomeśvara.

(2) Friday, Phālguna Amāvāsyā, Śaka 1389 (i.e., Friday, March 25, A.D. 1468), when a solar eclipse occurred at Skandasomeśvara.

(3) Friday, Bhādrapada Amāvāsyā, Śaka 1407 (i.e., Friday, September 9, A.D. 1485), when a solar eclipse occurred at Skandasomeśvara.

(4) Saturday, Āṣāḍha Pūrṇimā, Śaka 1408 (i.e., Saturday, June 17, A.D. 1486), when conjunction of Jupiter and Moon occurred at Skandasomeśvara.

(5) Sunday, Adhika Śrāvaṇa-śukla Pratipadā, Saka 1408 (i.e., Sunday, July 2, A.D. 1486).

Beginning:

Siddhiḥ. Śrīgaṇeśāya namaḥ.

Prakāśādityavatkhyāto bhāradvājo dvijottamaḥ I
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam II 1 II
Caitrādau vārasaṅkrāntitithyarkendūccasadhruvān I
Jñātvā'nyāṃścārkavarṣādāvājanma gaṇayettataḥ II 2 II

Caturdaśaśate śāke saṅkrāntitithayo jināḥ I
Rāśyādirbudhamadhyāhne rave rudrāḥ śarā mahī II 3 II
Indoḥ śivā rasāstriṃśaduccasyāṣṭau nṛpā ghanāḥ I
Ṣaḍarkatānā bhaumasya jñasyeṣu-dhṛti-vāyavaḥ II 4 II
Guroḥ khaṃ dhṛtayo rāmāḥ kṛtāmbudarasā bhṛgoḥ I
Śaneḥ samudrasūryābhraṃ rāhorvedāḥ khamabdhayaḥ II 5 II
Mandoccāṃśā raveraṣṭanagā atha kujāditaḥ I
Aṣṭārkāḥ khākṛtiḥ śūnyaghanāḥ khāṣṭau khasiddhakāḥ II 6 II
Pātā daśaghnā bhaumādervedākṣigajaṣaṭdiśaḥ I
Ayanaṃ tithayaḥ sārdhā *makarandoktamānase* II 7 II

End:

Atha lagnasādhanārthaṃ laṅkodayānāha —
Vasubhānyaṅkagodasrāstridantāśca kramotkramāt I
Tadvaccaraguṇārdhonā madhyaṣaṭke'nyathodayāḥ II 27 II

Vasubhādayo laṅkodayāḥ kramasthā utkramasthāśca
278, 299, 323, 323, 299, 278

Kramasthaiścaraguṇānāmardhai 60, 48, 20 rhīnāḥ 218, 251, 303 utkramasthaiśca 20, 48, 60 yutāḥ 343, 347, 338 karkā (The com. breaks off here).

The commentary is of the "Example" type (Udāharaṇa) and explains the rules by means of solved examples. It replaces the initial constants given by Mañjula by those for Wednesday noon, Caitrādi, Śaka 1400 (corresponding to March 4, A.D. 1478). These revised initial constants are taken, according to the commentator, from the Makaranda-mānasa, which was probably Makaranda's edition of the Laghumānasa with revised initial constants. It is noteworthy that Śaka 1400 is the epoch of the Makaranda-sāraṇī ("Makaranda's Tables").

The commentator gives a table of Jyās ("R. sines") for $R = 8°8'$ at intervals of $1°$, which is meant to replace the short table given by Mañjula, in order to get better results.

There are three quotations in the commentary, of which one is from the Bhāsvatī[1] of Śatānanda (A.D. 1099). The second is anonymous and seems to have been taken

[1]The passage quoted is Bhā. iv. 16 (c-d)-17 (a-b).

either from the Bhāsvatī or from the Karaṇa-kutūhala of Bhāskara II (A.D. 1150); it occurs in both the works.[1] The third has been ascribed to Mallikārjuna Sūri by Yallaya.[2]

Two features of the commentary are of special interest. These are:

(1) All calculations in chap. 3 are made for the town of Kāmpilya (modern Kampil, near Farrukhabad in Uttar Pradesh).

(2) Calculation of Dyugaṇa in chap. 1 is made for Wednesday noon, the 15th tithi of the light fortnight of Āṣāḍha, Śaka 1494 (corresponding to June 25, A.D. 1572).

(1) shows that the commentator belonged to Kāmpilya, and (1) and (2) taken together furnish good ground to infer that the commentator was the same person as Bhūdhara, the commentator of the Sūrya-siddhānta, who too belonged to Kāmpilya and in his commentary on the Sūrya-siddhānta calculated Ahargaṇa for the 15th tithi of the light fortnight of Āṣāḍha, Śaka 1494.

Since the Ahargaṇa has been calculated in the commentary for the 15th tithi of the light half of Āsāḍha, Śaka 1494 (i.e., for Wednesday, June 25, A.D. 1572), it is clear that the commentary was written sometime about that date.

From his commentary on the Sūrya-siddhānta, we learn that he belonged to Bharadvāja-kula and was the son of Devadatta and grandson of Khema Śarmā and lived at Kāmpilya situated on the bank of the river Gaṇgā (in Uttar Pradesh).

5.16. An anonymous commentary written in Karṇāta Deśa (Mysore State)

There exists a manuscript in the Government Oriental Library, Mysore, which contains the text of the Laghumānasa along with an anonymous commentary in Sanskrit written in Karṇāta Deśa (Karnataka or Mysore State). Its catalogue no. is B 581. We have designated it as F.

This commentary is incomplete and runs up to the end of the chapter on the lunar eclipse (Somagrahaṇādhikāra). It begins and ends thus:

Beginning:

Śrīḥ. Laghumānasamūlagranthaḥ. Śubhamastu.
Prakāśādityavat khyāto bhāradvājo dvijottamaḥ I
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam II
Caitrādau vārasaṅkrāntitithyarkendūccasadhruvān I
Jñātvā'nyāṃścārkavarṣādāvājanma gaṇayettataḥ II

[1]The vs. quoted is Bhā, i. 11 or KKu, i. 15.
[2]For this quotation see supra, passage 2 (2) on p. 54 (f.n.).

Kṛtaśaravasumitaśāke sauravāramadhyāhne ।
Rāśyādirajanṛpārkā ravirindurbhavadhṛ[ti]rdviyamāḥ ॥
Dyutkṛtikhāni yugotkṛtikarābdhayaḥ khāṣṭanavadaśatrisurāḥ ।
Go'ṣṭāviṃśatitānāḥ kujādayassūryabhagaṇānte ॥

Sūryādisaptagrahāṇāṃ dhruvarāśyādayo vakṣyante. Raveḥ ekādaśa, ṣoḍaśa, dvādaśa. Candrasya ekādaśa, aṣṭādaśa, dvāviṃśatiḥ. Kujasya dvau, ṣaḍviṃśatiḥ, śūnyaṃ. etc.

End:

Tatra sākṣivacanam —
Mīlanākhyo bhavetkālo vimardārdhena varjitaḥ ।
Unmīlanākhyaḥ saṃyuktaḥ sarvagrāse tu te ubhe ॥
Ardhādūnaṃ sadhūmraṃ syāt kṛṣṇamardhādhikaṃ tathā ।
Vimuñcataḥ kṛṣṇatāmraṃ kapilaṃ saṅkulagrahe ॥

Colophon:

Iti somagrahaṇādhikāraḥ samāptaḥ.

The commentary aims at clarifying the meaning of the text. It is frequently substantiated by corroborative verses (maṇḍanaślokas) and testimonia (sākṣivacana). Sometimes special rules are added. These are also substantiated by corroborative verses.

The commentator quotes from the Sūrya-siddhānta, the Bṛhatsaṃhitā of Varāhamihira, the Triśatikā of Śrīdhara, and the Siddhānta-śekhara of Śrīpati, without naming their sources or their authors.[1] The sources of the following quotations are not known at present:

(1) Dyugaṇānayane'ṣṭāṃśasvārko varṣāṃśasaṃyutaḥ ।
Svatriṃśāṃśena ṣaṣṭyaṃśaḥ yojyamiṣṭaṃ yathoditam ॥

(2) Aṣṭaghnakaraṇābdonaṃ śodhayettu yadā tadā ।
Saṣaṣṭitriśatān bhāgān bhāgasthāneṣu yojayet ॥

(3) Dyugaṇādhikamaṣṭaghnavarṣānyarkābda vā śake ।
Dyugaṇe sacakrāṃśe tyajecchiṣṭaṃ yathoditam ॥

(4) Liptā viliptā sūryasya gatirnavaśarā gajāḥ ।
Candrasya śūnyanandāśvā viṣayāgnaya eva ca ॥

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[1] The verses quoted are: SūSi, vi. 23; vii. 7, 18; BṛSaṁ, xvii. 3; Triś, Rule 12-13; and SiŚe, ii. 95.

Aṅgārakasya ca kṣoṇīvahnayo'ṅgāśvinau gatiḥ ।
Jñasya bāṇajinā dantā guroḥ pañcāmbaraṃ tathā ॥
Śukrasyāṅganavāṣṭau ca sūryajasyāśvinau viyat ।
Ṣaḍbhūvedā vidhūccasya rāhorvahnaya īśvaraḥ ॥[1]

(5) Jīve care ca dyugate valane cāyane tathā ।
Bhāgaliptā dvi..... sampradāyamitīritam ॥

(6) Ekaṃ catvāryaśaḥ ṣaḍghnaṃ dve sapta dvitāḍitam ।
Rāśiśūnyamathāṣṭaghnaṃ sarvaṃ ṣaṣṭyā samuddharet ॥

(7) Ravermadhyamameva syānmadhyamaṃ budhaśukrayoḥ ।
Śanyaṅgārakajīvānāṃ śīghroccaṃ ravimadhyamam ॥

(8) Guṇabāhvossamatve svaṃ śaśāṅke tvanyathā vyayaḥ ।
Gatāvasamatve svaṃ syād guṇakoṭyoḥ same tvṛṇam ॥

(9) Astodayoparāgeṣu yuddhe śṛṅgonnatau kramāt ।
Dṛkkarmasaṃskṛtādindoḥ tithināḍī vicārayet ॥

(10) Sūrye tulājādigate dinārdhaje chāyāyute dasrahṛte palaprabhā ।

(11) Madhyāhnabhe viṣuvato saṃśodhya dalitākṣabhā ।
Madhyāhnanatanāḍyastu dinārdhadyugatāntaram ॥

(12) Tatkālasāyanāṃśārkagamyāṃśā svodayairhatāḥ ।
Gamyāṃśakāśca khatryāptā gamyā yā tā vināḍikāḥ ॥
Tāḥ syuḥ sveṣṭavināḍībhyaḥ svodayāśca kramādgatāḥ ।
Yuñjyādekaikabhaṃ śiṣṭaṃ rātrau cedgatā tyajet ॥
Gatanāḍyutkramagrahāḥ viśiṣṭāṃśāyanaṃ tathā ।

(13) lagnārkayossādhanamiṣṭakālaiḥ ॥
..... yanayo gatagamyāntarodayaiḥ ।
Lagbakālo niśāśeṣe gamyabhuktāntarodayaiḥ ॥

(14) Saviturudayakālo'lpairiṣṭakālaiḥ kharāmaiḥ
guṇitamudayabhakte'ṃśonitārke vilagnāt ।
Ravitanuvivarāṃśaiḥ saṅguṇassvodayāsau
khaśikhivihṛtakālaścārkalagnaṃ ca bhānvoḥ ॥

(15) Gatagamyādiṣṭanāḍyāttriṃśaghnāḥ svodayoddhṛtāḥ ।
Bhāgādyairūnayukto'rko lagnaṃ tatsamaye yathā ॥

[1]These lines (with minor alteration in lines 4 and 5) occur in Yallaya's commentary also. Yallaya has called them interpolatory verses (prakṣipta śloka). They occur in Mss. H_1 and H_2 also.

Lagnārkāvekarāśisthau yadyantaralavāstayoḥ ।
Svodayena hatā nīlahṛtāḥ syuḥ praśnanādikāḥ ॥
Ravergantavyaghaṭikā yadā sveṣṭādhikāstadā ।
Nīlādiguṇitāḥ sveṣṭavināḍyaḥ svodayoddhṛtāḥ ॥
Bhāgāditadyuto bhānurlagnaṃ hīno'yanāṃśakaiḥ ।

(16) Ojāntāttu kṛtermūlaṃ mūlena yugalaṃ caret ।
Phalavargaṃ viśodhyauje dvighnaścārdhīkṛtaṃ padam ॥

(17) Guṇasyopari yaddhastaiśca guṇye dviṣthe dvidhākṛteḥ ।
Madhyayoryuktayoḥ ṣaṣṭyā cāptājopari yojayet ॥

(18) Iṣṭabhāgahatā bhaktā savitrā syātpadaprabhā ।
Pādaprabhā ravihatā svarāptā syāttadiṣṭabhā ॥

(19) Pūrvāhṇe'hardale hīne nate gataghaṭī bhavet ।
Aparāhṇe ghaṭīyuktāhardale gatanāḍikāḥ ॥ [1]

(20) Divasakareṇāstamayassamāgamaśśītaraśmiyuktānām ।
Bhaumādīnāṃ yuddhaṃ nigadyate'nyonyayuktānām ॥[2]

(21) Jayaḥ kṣepādhikātsaumye hīnakṣepaṃ tu dakṣiṇe ।
Ubhayorekamārgasthe bhinnamārge jayottare ॥[3]

(22) Tyaktvā bimbaṃ śaśāṅkasya tamobimbāddalīkṛtāt ।
Vargīkṛtāttataśśodhya vikṣepasya kṛtiṃ padam ॥
Sthityardhaṃ tu vimardārdhanāḍikādi phalaṃ smṛtam ।

(23) Mīlanākhyo bhavetkālo vimardārdhena varjitaḥ ।
Unmīlanākhyaḥ saṃyuktaḥ sarvagrāse tu te ubhe ॥

The commentator reads

Kṛtaśaravasumitaśāke caitrādau *sauravāra*madhyāhne

in place of

Kṛtaśaravasumitaśāke caitrādau *saurivāra*madhyāhne (LMā, vs. 1')

so, according to him, Caitrādi of Śaka 854 occurred on Sunday instead of Saturday as stated by Mañjula.

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[1]This vs. occurs in Ms. H_1 also. A similar verse has been quoted by the commentator Yallaya also.
[2]This verse has been quoted by the commentator Sūryadeva Yajvā also.
[3]A similar verse has been quoted by Praśastidhara and Yallaya.

A special feature of the commentary is that it uses the term lipti in the sense of liptā ("minute of arc"). The term liptā is also used. The term vilipti is similarly used in the sense of viliptā ("second of arc"). It also refers to the Catuṣpadi method of multiplication.[1]

The commentator hails from Karṇāta Deśa where the length of the equinoctial midday shadow measured 3 aṅgulas. He writes:

Asmin karṇāṭadeśe viṣuvacchāyā trīṇyaṅgulāni prasiddhāni i.e.,

"In this Karṇāta Deśa the equinoctial midday shadow is commonly known to be equal to 3 aṅgulas."

It means that the commentator belonged to a place which was situated in latitude 14°N., approximately.

The incomplete manuscript that is available to us does not provide any evidence as to the time when the commentary was written. It was indeed written after the time of Śrīpati whom the commentator quotes.

5.2. Commentaries in regional languages

It seems that the Laghumānasa was more popular in Āndhra and Kerala States where commentaries in the regional languages were also written. A commentary in Telugu was written by Ayyalu Somayāji Bālaya; another in Malayalam, entitled Mānasagaṇitam or Mānasocitam or Mānasam eṇṇum prakāram, was written by some anonymous writer.

5.21. Ayyalu Somayāji Bālaya's commentary in Telugu

One manuscript of this commentary exists in the Government Oriental Manuscripts Library, Madras:

Ms. No. R 337 (b). Laghumānasagaṇitam (with Telugu meaning). Folia 9a to 46b. Incomplete. Contains the first four adhyāyas, viz. (1) Madhyagrahādhyāya, (2) Sphuṭagrahādhyāya, (3) Candragrahaṇādhyāya, and (4) Sūryagrahaṇādhyāya.

The manuscript begins and ends thus:

Beginning: Ravicandragrahaṇālaku telaguṭīka.

ślo. Śrīveṅkaṭācalāvāsaṃ śrīnijāṃ (śāṃ) tabhujāntaram |
Vandārujanamandāraṃ vande kamapi sundaram ||

---

[1]This method is explained below. See under section 6 below.

ṭīka. Śrīveṅkaṭeśvarulaku namaskariñci grahaṇaśāstramu teluguśāyabūnini(na) vāḍanu ayalusomayājikulasaṃbhavuṃḍaina rāmacandrabhaṭlugārikinni accamaṃkunnu varaputruṃḍbāla (ya) yanavāḍanu kauṇḍinyagotrodbhavuṃḍanu nenu ī grahaṇaśāstrānaku teluguṭīka seyaṃbūni īṭīka cesina vatsaramāsadinavāralagnamunnāceppaṃ baḍenu.

ślo. Saptaikarkṣa-śaśāṅka-vatsaramite śāke yuvābde cirā
dāṣāḍhe bahule daśe gurudine strībālarāśyodaye ।
Śrītya (māsa)yyalusomayājakulajaśrīrāmacandrātmajaḥ
bālākhyo grahaṇākhyagrantharacanāṃ vakṣye'ndhrabhāṣātmikām ॥

ṭīka. Yuvasaṃvatsaramandu nijaāṣāḍhabahula daśamiguruvāramu nāḍu kanyālagnamandu īgranthamu telaguśāya būni nāṇḍunu.

ślo. Prakāśādityavat khyāto bhāradvājo dvijottamaḥ ।
Laghupūrvaṃ sphuṭopāyaṃ vakṣye'haṃ laghumānasam ॥

End:

tīka. Īcandrasūryagrahaṇabhedālu paṭṭelāgu 10 vighālu. Viḍi celāgu 10 vighālu. Ivi teliyanu devatalakai nanu śakyaṅgādanaṅgānu prākṛtajanulaku yemi cepyavalenu.

Colophon:

Iti śrīmañjālācāryasya kṛtau laghamānase sūryagrahaṇādhikāraścaturthaḥ.

Iti śri ayyalu somayājikulapārāvārasaṃjanitakauṇḍinyasagotra pavitra śrīrāmacandrācāryaputra bālayapraṇītaṃ daivajñamanollāsaṃvanu teluguṭīkayandu sūryagrahaṇādhyāyamu nālgavadi.

(vi-vi)

Nālgu adhyāyamulu vrāta vāguneyunndi. Tappulunnadi.

Idi mañjalācāryaviracita maina laghumānasamanu saṃskṛtagranthamunaku nayilu somayājibālayace raciyiṃpabaḍina teluguṭīka ī taṇḍu kauṇḍinyasagotruḍu. rāmacandrācāryuniputruḍu. talli accamu. ī ṭīkaku daivajñamanollāsamaniperu. adhyāyakramamu — (1) madhyagrahādhyāyamu. (2) sphuṭagrahādhyāyamu. (3) candragrahaṇādhyāyamu. (4) sūryagrahaṇādhyāyamu.

Folio 46b-47a.

Trairāśikaṃ decce sūtramu — anuśīrṣikato gonni ślokamulunu vāniki deluguṭīkayugaladu. (breaks off)

The commentary is called Daivajñamanollāsa. The commentator pays obeisance to the deity at Śrī Veṅkaṭācala, calls himself a son of Rāmacandra Bhaṭṭa and Accamā of Kauṇḍinya Gotra, and states that the commentary was written on Thursday, Nija Āṣāḍha Kṛṣṇa 10, Saṃvatasara Yuva, Śaka 1617, lagna Virgo (corresponding to Thursday, July 25, 1695)

The language of the commentary shows that the commentator belonged to Āndhra Pradeśa. But he was a devotee of God Venkaṭeśvara whose temple lies in Tamil Nadu near Tirupati.

5.22. Anonymous commentary in Malayalam

Two palm-leaf manuscripts (Nos. 5129 D and 5129 E) of this commentary, both incomplete, forming consecutive sections of the same codex, exist in the Kerala University Oriental Research Institute and Manuscripts Library, Trivandrum. The codex is about 200 years old.

The commentary in these manuscripts begins and ends thus:

Beginning:

Hariḥ Śrīgaṇapataye namaḥ. Śrīsūryādisarvagrahebhyo namaḥ.
Gaṇeśā ninnu vandiccen *Mānasam* kathayākuvān |
Mandacetassukalkkellām pāṭham ākkām itennaham ||

(The work begins with the commentary on vs. 3 of Lmā.)

Abdam vaccu pattil perukki appaṭi vaccu eṭṭil koṇṭu mel kūṭṭuka. Arupatil perukkikkoṇṭu tāzhattum vaykka. Pinne mūnru paṭi vaykka.

End:

Tīyati iliyil kūṭṭuka. Rāśi-tīyatiyil kūṭṭuka. Atu adhoyuti yākinratu. Bhujavum koṭivum ammārgameyuṇṭākki *jināśvino* irunūttirupattunālu hārakam āditvan.... (The mss. break off here).

The commentator does not mention his name anywhere in the commentary, but there are reasons to surmise that he was the same person as Puthumana Somayāji (A.D. 1732) of Śivapura[1], the author of Karaṇa-paddhati, Nyāya-ratna and several other works. For, K. Rama Varma Raja[2] states that Puthumana Somayāji was the author of a work entitled Mānasagaṇitam, and this Malayalam commentary (in the margin of the codex) calls itself Mānasam eṇṇum prakāram, this expression being a Malayalam

[1]Near Trichur in Kerala.
[2]See "The Brahmins of Kerala", Jour. of the Royal Asiatic Society (London), 1910, p. 635.

rendering of Mānasagaṇitam. Moreover, the Maṅgalācaraṇa (benedictory stanza) of this commentary seems to read like a Malayalam version of the Maṅgalācaraṇas in the Sanskrit works of Puthumana Somayāji.

6. Laghumānasa-based works

Besides the commentaries written on the Laghumānasa, two manuscripts containing calculation of solar and lunar eclipses based on the teachings of the Laghumānasa occur in the Government Oriental Library, Mysore. One is entitled

Laghumānasarītyā sūryacandragrahaṇānayanam

i.e., "Calculation of solar and lunar eclipses according to the methods taught in the Laghumānasa."

This manuscript occurs in the codes of Ms. No. B 583 just after the completion of Praśastidhara's commentary on the Laghumānasa. We have designated it as I_1. It begins and ends thus: [1]

Beginning:

Athaitallaghumānasarītya sūryacandragrahaṇānayanam.

Parābhavasaṃvatsarasya gataśakābdāḥ 1528 dhruvābdāḥ 428 tadānīṃ māghabahula 30 somavāsarasya mānasābdāḥ 428. "dhruvādyabdagaṇo digghnaḥ" iti dhruvābdagaṇaḥ 428 digghnaḥ 4280 "svakīyāṣṭāṃśaṃ" 525 taduparirāśau yutaṃ 4815 etc.

End:

Nataṃ 5-48 natonāhataviṃśatiḥ 82-21 mokṣakālapunarlambanaṃ 3-17 mokṣakālasthityardha(yuta)parva(ṇi) avaralambanaṃ saṃyojya mokṣakālaḥ 25-8 mokṣakālāt sparśakālaṃ tyaktvā saṃyojya mokṣakālaḥ 25-8 mokṣakālāt sparśakālaṃ tyaktvā ādyantapuṇyakālaḥ 4-11 grāsaliptā 15-53 uttaravikṣepavaśād vāyavyasparśa īśānyamokṣaṃ. Uttaragolaṃ — (The manuscript breaks off here).

The manuscript is evidently incomplete. It contains the calculation of the solar eclipse that occurred at a place in latitude 14°15′ N. (corresponding to equinoctial midday shadow equal to 3 aṅgulas 30 vyaṅgulas) and longitude 22 yojanas east of the Hindu prime meridian on Monday towards the end of the 15th tithi of the dark fortnight of Māgha in Saṃvatsara Parābhava, Śaka 1528 (i.e., Monday, February 16, A.D. 1607). The calculation of the lunar eclipse which must have occurred in the manuscript after the calculation of the solar eclipse is missing from the manuscript.

[1] Another incomplete manuscript of Laghumānasarītyā sūryacandragrahaṇānayanam occurs in the Government Oriental Library, Mysore (Ms. No. B 581 C). It consists of 3 folia only. We have designated it as I_2.

However, there is another manuscript in the same codex occurring just after the above-mentioned manuscript which contains the calculation of a lunar eclipse that took place at a place in the same latitude and longitude 38 yojanas east of the Hindu prime meridian on Thursday towards the end of the 15th tithi of the light fortnight of Pauṣa in Saṃvatsara Prabhava, Śaka 1549 (i.e., Thursday, January 10, A.D. 1628). This manuscript is in Telugu. We have designated it as J. It begins and ends thus:

Beginning:

Prabhavasaṃvatsarasya gataśakābdāḥ 1549 khakhaśaśibidhumitaśāke ani śakābdālonu 1100 yivibuccagātaina mānasakaraṇābdāḥ 449 caitrādititthayaḥ 314 puṣyaśuddha 15 guruvāraṃ nāṭikidyugaṇaṃ devalaśi "dhruvādyabdagaṇo digghna" ani dhruvābdālu 10 guṇiyina prati 4490 etc.

End:

Sparśakāla 17-17 nimīlanakāla 21-25 unmīlanakāla 23-49 mokṣakāla 26-27 mokṣakālamulonu sparśakālamubuccaṅgānu ādyantapuṇyakāla..... mulonu nimīlanakālamubuccaṅgānu bimbadṛśyakālamauṃu. Parva grāsugankugrāsaliptulatonu candrabimbaṃliptamaunu pātonakendraṃ. Meṣādiganuka āgneyasparśa nairṛtyamokṣamu dakṣiṇagolam.

Vilambisaṃ āśvinamāsa candragrahaṇakke telaguṭīku samāptaṃ. Śrīḥ. 9-11-98 mūgūka...

The following features of these manuscripts deserve special notice:

(1) Although the calculation of the eclipses are made for the Śaka years 1528 and 1549, the Caitrādi of Śaka 1100 has been taken as the epoch of calculation. This is against the instruction of Mañjula that the rules of the Laghumānasa were meant to be used for 100 years from the epoch of calculation. If the computations were made after 100 years from the epoch, the results might not be correct.

(2) Use has been made of two new corrections to the mean longitudes of the planets, viz. (i) Caitrādi correction, and (ii) Bīja correction.

In the case of the Sun, Moon, Moon's apogee and Moon's ascending node, the amounts of these corrections are as follows:

	Caitrādi correction in mins.	*Bīja* correction
Sun	− T/149	Nil
Moon	− T/141	+ 10Y/200
Moon's apogee	+ T/61	− 10Y/80
Moon's asc. node	Nil	− 10Y/127

where T denotes Caitrādi tithis and Y the number of years elapsed since the epoch.

These corrections as well as the initial constants for the Caitrādi of Śaka 1100 and for the beginning of the mean solar year occurring in Śaka 1100 are also found to be stated in the interpolatory verses given in Mss. H_1 and H_2. Ms. H_1 gives the bīja corrections for Mars etc. also.

It seems that the Caitrādi and Bīja corrections were introduced to get rid of the errors caused by making the calculations more than 100 years after the epoch of calculation.

(3) Use of precession of the equinoxes at the rate of 50″ per annum.

This is an improvement over the rate of 1′ per annum adopted by Mañjula.

Ms. H_1 takes the rate of precession at 54″ per annum.

(4) Use of the so called Catuṣprati method (Catuṣprati-nyāya) of multiplication.

This may be explained by an example as follows:

Example. Multiply 3°40′ by 2°12′.

Writing the degrees and minutes of the multiplicand and the multipler one below the other, we get

3	2
40	12

Applying the Catuṣprati method of multiplication, we get

$$3\times 2 = 6 \text{ degrees}$$
$$3\times 12 + 2\times 40 = 116 \text{ minutes}$$
$$40\times 12 = 480 \text{ seconds}$$

i.e., 8°4′.

This method has been used in Ms. F also where it is called Catuṣpadi-nyāya. This is perhaps the correct term.

Sumati Harṣa (A.D. 1619), in his commentary on Bhāskara II's Karaṇa-Kutūhala, calls this method by the name Gomūtrikā.

(5) Calculation of Rsines by using true multipliers prescribed by Mallikārjuna Sūri.

See infra, my notes on LMā, vs. 12.

7. Impact on later works

The Laghumānasa due to its novelties and unprecedented rules and methods attracted many an astronomer hailing from far-flung places in India, and had a great impact on their writings. Some of the rules given by Mañjula became classical and were adopted in some way or the other by posterior writers. Bhojarāja (A.D. 1042), a Paramāra king of Dhārā in Mālava country, in his celebrated Rājamṛgāṅka, and Citrabhānu (A.D. 1530) resident of Covvuram (Skt. Śivapura) near Trichur in Kerala, in his Karaṇāmṛta, have not only taken several rules invented by Mañjula but also adopted a number of passages from the Laghumānasa without any or with slight alteration. Astronomers of Āndhra Pradeśa, such as Sūrya Sūri or Sūryācārya (A.D. 1460), teacher of Yallaya (A.D. 1482), in his Gaṇakānanda, Mallaya Yajvā (A.D. 1596), in his Siddhānta-sāra, Vīra Sūri (A.D. 1606), son of Koṭṭacenna, in his Siddhānta-saṅgraha, and Tamma Yajvā (A.D. 1613), son of Mallaya Yajvā, in his Grahagaṇita-bhāskara, have also adopted several rules of Mañjula. Daśabala, the author of Cintāmaṇi-saraṇikā and the Karaṇa-kamala-martaṇḍa, in the latter work has adopted Mañjula's formula for the evection and improved Mañjula's method for finding the hour-angle from the day-length. For details see Appendices 3 and 4 to the Sanskrit text. Astronomer Acyuta (died A.D. 1621) of Kerala, too, has framed several of the rules given in his Karaṇottama on the model of those stated in the Laghumānasa.

8. Popularity of Laghumānasa

The Laghumānasa was written in A.D. 932 and it soon attained its status as an important work on astronomy. It is not known where exactly its author Mañjula lived and wrote this work but there is no doubt that within a few years the merit of this work was established and its fame reached Kashmir and only 26 years after its composition, the Kashmirean astronomer Praśastidhara regarded it as a suitable work for writing a commentary on it. Writes he:

> "Since this work is small, written with no less effort, accurate and universal, and computations based on it accord with observation, I deem it a great honour in writing a commentary on it."

Praśastidhara's commentary explained the text and demonstrated the working of the rules by solving typical problems in astronomy and continued to be used for a long time. The use of this commentary was not confined to Kashmir alone. Its fame reached as far south as Gaṅgai-koṇḍa-Colapuram (in south Tamil Nadu). The celebrated commentator Sūryadeva Yajvā who belonged to that place has mentioned it and recommended its use.

Sūryadeva Yajvā himself greatly appreciated the teachings of the Laghumānasa, so much so that in A.D. 1248 at an advanced age of 56 years he took upon himself the task of writing a super commentary on it in which he gave not only the full exposition of the text but also the basic and abridged rationales of the rules. He, however, did not demonstrate the working of the rules by giving worked out examples as this was already done by Praśastidhara. For those interested in such demonstration he advised to consult Praśastidhara's commentary.

About 234 years thereafter astronomer Yallaya, resident of the town Skanda-someśvara in Āndhra Pradeśa, wrote a fairly large commentary in which he tried to incorporate everything given by his predecessors Praśastidhara and Sūryadeva Yajvā, briefly and in his own way. This commentary explained the text and also demonstrated the working of the rules by adding worked out examples.

The commentaries written by Praśastidhara, Sūryadeva Yajvā and Yallaya were very detailed and were meant for advanced and serious students of the subject. They did not cater to the needs of ordinary students who needed simply the bare meaning of the text and the stepwise application of the rules. This need was fulfilled by the commentaries written by Parameśvara of the village Ālattūr in South Malabar, Bhūdhara of the town Kāmpilya in Uttar Pradesh, and the anonymous commentator failing from Karṇāta Deśa (Mysore State).

Two names, viz. Mallikārjuna Sūri of Āndhra Pradeśa and Makaranda of Uttar Pradesh, deserve special mention in connection with the Laghumānasa. The contribution made by them has been referred to by the commentators particularly Yallaya and Bhūdhara. There are reasons to believe that they also wrote commentaries on the Laghumānasa. These commentaries are not extant.

From the above it is clear that the Laghumānasa was studied in Kashmir, Uttar Pradesh, Āndhra Pradeśa, Karnataka, Tamil Nadu, and Kerala. The adoption of the rules devised by Mañjula in the Rājamṛgānka of Bhojarāja of Dhārā and the Karaṇa-kamala-mārtaṇḍa of Daśabala and reference to Mañjula in the Siddhānta-śiromaṇi of Bhāskara II of Bīḍa in Mahārāṣṭra shows that the works of Mañjula were studied in Malwa, Gujarat and Mahārāṣṭra as well.

Āndhra Pradeśa and Kerala, however, seem to be the states where the Laghumānasa was comparatively more popular, because works on astronomy written in these states bear clear impact of this work. Moreover, commentaries on the Laghumānasa are known to have been written in the local vernculars of these states (viz. Telugu and Malayalam). The Telugu commentary was written in A.D. 1695 and the Malayalam commentary in A.D. 1732 which shows that the Laghumānasa was popular in these states even in the seventeenth and eighteenth centuries A.D.

The Laghumānasa seems to have been studied in Nepal also. Astronomer Sridatta, who wrote his commentary on the Khaṇḍakhādyaka of Brahmagupta in A.D. 1532, makes mention of Mañjāla in that commentary.

We have so far not been able to discover any tables (sāraṇī) constructed on the basis of the Laghumānasa. However, the existence of the manuscripts (I_1 and I_2) giving calculations of a solar eclipse and a lunar eclipse based on the teachings of the Laghumānasa and the use of the Caitrādi and Bīja corrections to the planets using epochal constants for A.D. 1178 seem to suggest that astronomers of the Āndhra Pradeśa prepared their Pañcāṅgas on the basis of the Laghumānasa. Mallikārjuna Sūri might have been the promulgator of this practice. It may be added that these manuscripts employ the multipliers devised by Mallikārjuna Sūri to calculate Rsines and Rcosines.

We have so far no information regarding the popularity of the Laghumānasa in the other states not mentioned above. There is, however, no doubt that this work was generally studied in most parts of India. In some parts of India it was studied even in the eighteenth century A.D.

9. Editorial Note

9.1. Manuscripts used

Eleven manuscripts designated as A_1, A_2, B, C, D_1, D_2, E, F, G, H_1, and H_2, including the printed edition of the Ānandāśrama Sanskrit Series designated as C, have been used in editing the text of the Laghumānasa. The manuscripts designated as I_1, I_2 and J, not containing the text, have also been consulted occasionally.

A_1 Ms. No. B 583 of the Government Oriental Library, Mysore, (now Oriental Research Institute, Mysore), Containing the text along with the commentary of Praśastidhara. Extent 30 ff. Complete.

We have used its transcript in Devanāgarī characters existing in the Lucknow University Library, Lucknow. Accession No. 47065.

A_2 Ms. No. B 581-A of the Government Oriental Library, Mysore. Containing the text along with the commentary of Praśastidhara. Size — 20 cm. × 15 cm., written lengthwise, 14 lines in a page and 32 letters in a line. Extent — 10 ff. Incomplete. Contains Adhikāras 1 and 2 only.

We have used its transcript in Devanāgarī characters procured through Prof. K.V. Sarma.

B. This is comprised of two complementary manuscripts, viz.

(i) Ms. No. R 2741 of the Government Oriental Manuscripts Library, Madras. Containing the text along with the commentary of Sūryadeva Yajvā. Extent — 190 ff. Character — Grantha. Incomplete. Starting from the beginning, it runs up to commentary on verse 5 of the last chapter (vs. 55 of our text) in the midst of which it breaks off.

(ii) Ms. No. R 3037 of the Government Oriental Manuscripts Library, Madras. Containing the text along with the commentary of Sūryadeva Yajvā. Extent — 30 ff. Character — Grantha. Incomplete. Starting from the midst of commentary on vs. 5 of the last chapter, it runs up to the end of the commentary.

We have used transcripts in Devanāgarī characters of these manuscripts existing in A.N. Singh Collection (No. 35). Both transcripts taken together give full text along with the commentary of Sūryadeva Yajvā.

C. Text with the commentary of Parameśvara. Edited by B.D. Apte and published in Ānandāśrama Sanskrit Series (No. 123) in A.D. 1944.

D_1 Ms. No. B 580 of the Government Oriental Library, Mysore. Containing the text along with the commentary of Yallaya. Extent — 107 ff. Complete (but some portion in the beginning missing).

We have used the transcript existing in the Lucknow University Library, Lucknow, Accession No. 404188.

D_2 Ms. with Serial No. 37292 of the Sampurnanand Sanskrit University Library, Varanasi. Containing the text along with the commentary of Yallaya. Size — 8.1 × 4.5 inches: 10 lines in a page and 27 letters in a line. Script — Devanāgarī. Extent — 2-29 ff. Incomplete. Contains com. on ch. 1 complete; breaks off in the midst of com. on vss. 1-2 of ch. 2 (same as vss. 11-12 of our text); restarts in the midst of com. on vs. 10 of ch. 2 (same as vs. 21 of our text); and continues up to com. on vs. 4 of ch. 3 (same as vs. 24 of our text) in the midst of which it breaks off.

We have used its transcript existing in A.N. Singh Collection (No. 29).

E. Ms. with Serial No. 36944 and Acc. No. 2970 of the Sampurnanand Sanskrit University Library, Varanasi. Containing the text along with an anonymous commentary (probably on Bhūdhara). Size — 8.1 × 4.3 inches. Extent — 12 ff. with 9 lines in a page and 31 letters in a line. Script — Devanāgarī. Incomplete. Breaks off in the midst of commentary on vs. 3 of ch. 3 (same as vs. 23 of our text).

F. Ms. No. B 581-B of the Government Oriental Manuscripts Library, Mysore. Containing an anonymous commentary in Sanskrit. Extent — 28 ff. with 18 lines in a page and 17 letters in a line. Incomplete. (Complete up to Somagrahaṇādhikāra).

We have used its transcript in Devanāgarī characters procured through Prof. K.V. Sarma.

G. Ms. with Serial No. 36942 and Acc. No. 2968 of the Sampurnanand Sanskrit University Library, Varanasi. Containing the text only. Size — 7.9 × 4.2 inches. Extent — 7ff. with 9 lines in a page and 26 letters in a line. Script — Devanāgarī. Complete.

H_1 Ms. No. R 2472f of the Government Oriental Manuscripts Library, Madras[1]. Containing the text intermixed with some interpolatory verses. Size — 10¾ × 9¼ inches. Script — Telugu. Incomplete. (Verses corresponding to nos. 51, 52, 57, 58, 59 and 60 of our text missing.)

We have used its transcript in Devanāgarī characters procured through Prof. K.V. Sarma.

This manuscript contains a number of interpolatory verses, giving among other things the following:

(1) initial constants (Pūrva-dhruvas) for Tuesday noon, Caitrādi, Śaka 1100 (corresponding to March 21, A.D. 1178).

(2) Bīja corrections starting from Śaka 1100, and

(3) Caitrādi corrections.

These have been used in Mss. I_1 and I_2 (described below) to compute the longtitudes of the Sun, Moon, Moon's apogee and Moon's ascending node.

Three interpolatory verses (liptā viliptāḥ sūryasya etc.) giving mean daily motion of the planets, occur in Yallaya's commentary also. Similarly, two interpolatory verses (gataiṣyhaṇḍa etc.) and 1½ interpolatory verses (chedā jināśino etc.) occur in Mss. A_1 and C also.

3-30 (standing for 3 aṅgulas 30 vyaṅgulas) inserted after the word viṣuvacchāyā in vs. 22 shows that the manuscript was written somewhere in latitude 14°15′N.

H_2 This manuscript forms the appendix of Ms. H_1 and begins where H_1 ends. Like H_1 it contains the text intermixed with a number of interpolatory verses. Incomplete. Verses 1, 2, 8, 9, 10 (a-b), 13, 15-19, 21, 23-32, 34 (a-b), 35-38, 39 (c-d), 40 (c-d)-42, 45-60 are missing. Text corrupt.

The interpolatory vss. in this manuscript too include verses giving

(1) initial constants for Tuesday noon, Caitrādi, Śaka 1100, and

[1]The codex R 2472 in 148 pages is a copy of a palmleaf manuscript prepared in 1917-18.

(2) Caitrādi corrections.

These verses are the same as in H_1. The 1½ verses, chedā jināśvino etc., occur in this manuscript also. The other interpolatory verses which are many and different from those found in H_1 are very corrupt.

I_1 This manuscript occurs just after the commentary of Praśastidhara in the codex of Ms. No. B 583 of the Government Oriental Library, Mysore, described above.

It contains calculation of the solar eclipse that occurred at a place in latitude 14°15′N. (corresponding to equinoctial midday shadow equal to 3 aṅgulas 30 vyaṅgulas) and longitude 22 yojanas east of the Hindu prime meridian on Monday, Māgha-bahula 30, Saṃvatsara Parābhava, Śaka 1528, February 16, A.D. 1607. It uses the initial constants for Tuesday noon, Caitrādi, Śaka 1100, as well as the Bīja and Caitrādi corrections as given in H_1 and H_2.

I_2 Ms. No. B 581-C of the Government Oriental Library, Mysore. This is another but incomplete copy of I_1. It runs up to the calculation of the Moon's ascending node (rāhu). Extent — 3 ff, written breadthwise with 16 lines in a page and 15 letters in a line.

We have used its transcript in Devanāgarī characters procured through Prof. K.V. Sarma.

J. This manuscript occurs just after I_1 in the codex of Ms. B 583 of the Government Oriental Library, Mysore. It is in Telugu language.

It contains calculation of the lunar eclipse that occurred at a place in latitude 14°15′N. and longitude 38 yojanas east of the Hindu prime meridian on Thursday, Pauṣa Śukla 15, Saṃvatsara Prabhava, Śaka 1549, January 10, A.D. 1628. Here also use is made of the same initial constants and the same Bīja and Caitrādi corrections as in I_1.

9.2. Edited text

The text exhibited by the manuscripts was found to vary at places. Whenever variations in readings were noticed, the readings adopted were those which were considered to be correct and more appropriate than the others. The other readings have been shown in the apparatus criticus.

The manuscripts differed in the chapterwise arrangement and also in the numbering of the verses. In the chapterwise arrangement of the verses we have followed the commentator Prāśastidhara, differing only in one respect that we have bifurcated his eighth chapter designated as Mahāpātenduśṛṅgonnatyadhikāra by him into two chapters called Mahāpātādhikāra and Candraśṛṅgonnatyadhikāra. Our edited text therefore contains 9 chapters in place of 8 of Praśastidhara. The verses of each chapter are numbered serially as usual. But for the convenience of reference continuous numbering has also been provided to the whole text. This continuous numbering occurs at the ends of the verses. Five verses giving the initial epochal constants which were not of permanent use and did not form part of the text proper have been numbered separately as 1′, 2′, 3′, 4′ and 5′. Moreover, two verses which were added to the text by the commentator Yallaya after verses 53 and 58 have been numbered 53′ and 58′ to distinguish them from the 60 verses of the text which were found in the earlier texts.

Verses dealing with different topics or subtopics or giving different rules have been set apart and prefixed by an introductory heading briefly summarizing their contents. These introductory headings did not occur in the manuscripts and have been enclosed within brackets. To distinguish the words or word-chronograms denoting numbers, the numbers represented by them have been inserted after them and enclosed within brackets.

Towards the end of the Sanskrit text the following six appendices have been added:

(1) Concordance of verses of the various manuscripts.

(2) Arrangement of verses in the various manuscripts.

(3) Verses of the Laghumānasa adopted in later works.

(4) Rules invented by Mañjula in later works.

(5) Index of half-verses.

(6) Index of technical terms.

9.3. English translation

The Sanskrit text is followed by English translation and commentary. Effort has been made to provide, as far as possible, a literal rendering of the text into English. At the same time care has been taken to ensure that it is clear and easily understandable. The portions of the English translation enclosed within brackets did not occur in the text and have been given in the translation to make it clear and understandable and are, at places, explanatory. Without these portions, translation at those places might appear meaningless to the reader who cannot consult the original for lack of knowledge of Sanskrit. Attempt has been made to keep the spirit of the original and as far as possible the sequence of the text is unaltered. Sanskrit technical terms having no equivalents in English have been retained as such in the translation. They have been explained in the subjoined commentary.

Verses giving the same rules have been translated together and are prefixed by an introductory heading briefly summarizing their contents.

The translation of each rule is followed by short notes and comments comprising: (1) elucidation of the text where necessary, (2) rationale of the rule given in the text, (3) illustrative solved examples where necessary, (4) critical notes, and (5) other relevant matter, depending on the passage translated. In doing so vast literature, published and unpublished, has been consulted and parallel passages occurring elsewhere have been noted in the footnotes. This has been of considerable help in understanding and translating the text.

The typing of Sanskrit matter in Devanāgarī is inconvenient and offers great difficulty, particularly when it is mixed up with matter in English. To avoid this inconvenience, Sanskrit matter whenever it occurs in the present work has been typed in Roman script. The scheme of transliteration of Devanāgarī into Roman is given at the very beginning of this work for the convenience of the reader.

LAGHUMĀNASA

SANSKRIT TEXT

Manuscripts Used

A_1 Lucknow 47065. Text with Praśastidhara's com. Complete.

A_2 Mysore B 581 A. Text with Praśastidhara's com. Incomplete. (Two adhikāras only)

B A.N. Singh Collection 35. Text with Sūryadeva Yajvā's com. Complete.

C Ânandāśrama Sanskrit Series 123. Text with Parameśvara's com. Complete.

D_1 Lucknow 404188. Text with Yallaya's com. Complete.

D_2 A.N. Singh Collection 29. Text with Yallaya's com. Incomplete. (Up to vs. 24, vss. 13 to 21 missing)

E Varanasi 36944. Text with Bhūdhara's comm. Incomplete. (Up to vs. 27)

F Mysore B 581. Text with an anonymous com. by some Mysorean. Incomplete. (Up to vs. 38)

G Varanasi 36942. Text only. Complete.

H_1 Madras R 2472f. Text wtih some interpolatory vss. Incomplete. (Vss. 51, 52, 57-60 missing)

H_2 Madras R 2472f. Text with some interpolatory vss. Incomplete. (Several vss. missing)

Śrīmañjulācāryapraṇītaṃ

Laghumānasam

ATHA DHRUVAKANIRŪPAṆĀDHIKĀRAḤ PRATHAMAḤ

(Granthakartṛparicayapūrvakaṃ granthaprayojanākhyānam)

1. Prakāśādityavat khyāto bhāradvājo divjottamaḥ ।
Laghvapūrvasphuṭopāyaṃ vakṣye'nyallaghumānasam ॥ (1)

(Granthaprayogavidhānam)

2. Caitrādau vārasaṅkrāntitithyarkendūccasadhruvān ।
Jñāvā'nyāṃścārkavarṣādāvājanma gaṇayettataḥ ॥ (2)

(Granthakāranibaddha-pūrvadhruvakāḥ)

1′. Kṛtaśaravasu(854)mitaśāke
caitrādau saurivāramadhyāhne/
Rāśyādirajanṛpārkā (11^s 16° 12′)
ravirindurbhavadhṛtidviyamāḥ (11^s 18° 22′) ॥ (1′)

2′. Sūryānmandoccāṃśā vasuturagāḥ (78°)
parvatāstu satryaṃśāḥ (7⅓°) ।
Svararavavayaḥ (127°) khākṛtayo (220°)
dvinagabhuvo(172°)'śīti(80°)radrijināḥ (247°) ॥ (2′)

3′. Dvyutkṛtikhāni (2^s 26° 0′) yugotkṛtikarābdhayaḥ (4^s 26° 42′)
khāṣṭanava(0^s 8° 9′)daśatrisurāḥ (10^s 3° 33′) ।
Go'ṣṭāviṃśatitānāḥ (9^s 28° 49′)
kujādayassūryabhagaṇānte ॥ (3′)

Apparatus

1c. D_1 D_2 G: laghvapūrvaṃ sphuṭopāyaṃ. Bālaya: laghupūrvaṃ sphuṭopāyaṃ.
2b. D_1 D_2 G: okadhruvān.
2d. D_1: The commentator Yallaya mentions the reading śatābdānte punaścaret in place of ājanma gaṇayettataḥ, but the sentence which gives this reading does not occur in D_2.
1′b. F: sauravāra°. (Sauravāra means Sunday and saurivāra Saturday). G too takes ravivāsara. See infra, f.n. to 5′d.
2′b. C: parvatāśca. B puts this verse after vs. 4′.
3′b. Sūryadeva Yajvā refers to the reading °daśatriradāḥ.

Adoption

Vs. 2′ has been adopted in the Karaṇāmṛta of Citrabhānu after suppressing the statement of position of the Moon's apogee. Vs. 2′(c-d) is exactly the same. See KA (= Karaṇāmṛta), i. 19½.

4′. Saṅkrāntitithidhruvakāḥ śakrā (14)
vasunavaraseṣavo (8^s 9° 56′) rāhoḥ ।
Kṛtayamavasurasadaśakā (4, 2, 8, 6, 10)
daśā(10)hatāḥ śeṣapātāṃśāḥ ॥ (4′)

5′. Ayanacalanāṣṣaḍaṃśāḥ pañcāśalliptikā(6°50′)stathaikaikāḥ(1′) ।
Pratyabdaṃ tatsahito raviruttaraviṣuvadādiḥ syāt ॥ (5′)

Iti laghumānase dhruvakanirūpanādhikāraḥ prathamaḥ.

Apparatus
5′ b. C: °kaikam. F: °kailā.
5′d. A_1: °dādau.
Note 1. After vs. 5′, A_1 A_2 state, explain and illustrate by an example the following verse:
Antarayukte hīne bhānau candrādhike kramādūne ।
Cakrone śataguṇite svaranidhibhakte tu saṅkramatithiḥsyāt ॥
2. In place of vss. 1′-5′, G gives the following 9 verses:
Kṛteṣvibhamite śāke madhyāhne *ravivāsare* ।
Caitrādau dhruvakān vakṣye ravicandrendutuṅgajān ॥
Rāśyādyarkadhruvo rudrā nṛpārkau khamanū kramāt ।
Indorbhavāśca dhṛtayo dviyamāḥ khamiti kramāt ॥
Uccasya dhruva(kaḥ) śūnyaṃ satryaṃśā atha parvatāḥ ।
Kujasya dvyutkṛtirkhāni yugotkṛtikarābdhayaḥ ॥
Jñasya khāṣṭanavejyasya kaverdaśaguṇāḥ surāḥ ।
Go'ṣṭāviṃśatitānāśca dhruvaḥ śānaiścaro bhavet ॥
Vasavo yugaṣaḍbāṇā vilomāścandrapātajāḥ ।
Ravivarṣamukhe bhaumapūrvāṇāṃ dhruvakā amī ॥
Ravernandeṣavo'ṣṭau ca khagośailāḥ śarāgnayaḥ ।
Candrasya ca taduccasya rasā rūpābdhayastathā ॥
Kujasya bhuktiḥ kramaśo rūpāgnī atha ṣaḍyamau ।
Pañcābdhipakṣāśca yamāgnayo bhuktirbudhasya ca ॥
Pañcejyasya ca saṇṇandā aṣṭau ca bhṛgunandanaḥ ।
Śaneśca dasrau pātasya gantā rudrā gatirbhavet ॥
Gajāśvāśca svarādityā khākṛtirdvinagendavaḥ ।
Khāṣṭau saptajinā ravyādyuccāṃśastatra varjitāḥ ॥

Col. A_1 A_2: Iti dhruvakanirūpaṇādhikāraḥ prathamaḥ.
C D_1 D_2 E F G: No colophon as the chapter is not ended here.
H_1: Iti mañjulācāryakṛte laghumānase sphuṭagatyadhikāraḥ.

ATHA MADHYAMAGATYADHIKĀRAḤ DVITĪYAḤ

(Dyugaṇānayanam)

1. Dhruvādyabdagaṇo dig(10)ghnassvakīyāṣṭāṃśasaṃyutaḥ I
Saṅkrāntitithiyukto'dhaḥ svaṣaṣṭyaṃśavivarjitaḥ II (3)

2. Triṃśacchinnāvaśeṣonaścaitrādititithibhiryutaḥ I
Triguṇābdagatartūno dyugaṇo dhruvavāsarāt II (4)

(Ravimadhyamānayanam)

3. Dyugaṇo'dho daśaghnābdayutaḥ khāgā(70)ptavarjitaḥ I
Aṣṭaghnābdonito'rkāṃ(12)śāḥ prakṣepyo'bdāṣṭamaḥ kalāḥ II (5)

(Candramadhyamānayanam)

4. Viśva(13)ghno dyugaṇo dviṣṭhastrighnābdadyugaṇonitaḥ I
Aṣṭāṅgā(68)ptajina(24)ghnābdayuto bhāgādikaḥ śaśī II (6)

(Candroccamadhyamānayanam)

5. Dyugaṇo dvi(2)guṇābdonaścandroccāṃśā navoddhṛtāḥ I
Khaveda(40)ghnābdasaṃyuktāssāṣṭāṃ(8)śābdakalonitāḥ II (7)

(Bhaumamadhyamānayanam)

Apparatus

1. Before vs. 1, G adds:
Śākaḥ kṛtesvibhai(854)rūno dhruvādyabdagaṇo bhavet I
Tatrārkavārasaṃkrāntitithi rudra(11)mitā bhavet II
1a. B: dhruvāda°.
1c. H_1: °tithisaṃyukto.
1d. A_1 F: 'iha svaṣaṣṭyaṃśonitāt svataḥ. A_2: svakīyāṣṭāṃśasaṃyutaḥ. G: svasaṣṭyaṃśavinā kṛtaḥ.
2a. D_1: triṃśadbhaktā°. D_2: triṃśacchinnā°. H_1 H_2: triṃśadbhinnā.
3 (a-b). A_1F: °bdayuk svakhādryāptavarjitaḥ. D_1: khādryāptavarjitaḥ.
3 (c-d). A_1 B: māḥ kalāḥ. D_1: 'rkāṃśo'bdāṣṭamāṃśa kalānvitāḥ.
D_2 E G H_1 H_2: prakṣepo'bdāṣṭamaḥ kaḷāḥ. F: prakṣepyābdāṣṭamāḥ kalāḥ.
4a. E G: 'dhaḥsthaḥ in place of dviṣṭhaḥ.
4 (c-d). G: aṣṭāṃgāpto. B C: bhāgāditaḥ.
5 (a-b). C: dyugaṇād dviguṇābdonāccandroccāṃśā navoddhṛtāḥ.

6. Dhruvādyarkāt kujo dvābhyāṃ (2) nṛpa(16)ghnācceṣukheṣubhiḥ (505) I

(Budhaśīghroccānayanam)

Sapta(7)ghnādṛtuvedai(46)ghnaścatur(4)ghnaraviṇā yutaḥ II (8)

(Gurumadhyamānayanam)

7. Rūpa(1)ghnādbhāskarairjīvo bhū(1)ghnācca radakhendubhiḥ (1032) I

(Śukraśīghroccānayanam)

Dig(10)ghnāt ṣaḍ(6)bhissito dig(10)ghnāt trijināṃ(243)śena varjitaḥ II (9)

(Śanimadhyamānayanam)

8. Ṣaḍguṇādayute(10000)nārkiścandra (1) ghnācca khavahnibhiḥ I

(Candrapātānayanam)

Nakhaiḥ (20) pañcāṅganetrai(265)śca candrapāto vilomagaḥ II (10)

Iti laghumānase madhyamagatyadhikāro dvitīyaḥ.

6a. G: dvyāpto for dvābhyāṃ.
6c. G: °ghnādrasavedai°.
7a. G: bhūmighnādravibhirjīvo. H_1: candraghnācca.
7 (c-d): A_1 F: śukro'kṣaghnāt tribhirdighhnāt, but Praśastidhara comments the reading digghnāt ṣadbhiḥ sito digghnāt which occurs in A_2; G: conitaḥ for varjitaḥ.
8a. A_1: trighnādārkiḥ khakhābhrākṣaiḥ. A_2: ṣaḍguṇādayutenārkiḥ. Praśastidhara comments the latter reading.
8d. G: candrapāto'tha sadhruvāḥ.
Note 1. D_1 D_2 put vs. 20 after vs. 10 above.
2. A_2 breaks off after the colophon of this chapter.
Col. A_1 A_2: iti mānasakaraṇe madhyamādhikāro dvitīyaḥ.
B: No colophon but madhyamādhikāra ends here.
C: iti madhyamavidhiḥ.
D_1D_2: iti ... madhyagrahādhikāraḥ.
E: iti madhyamādhikāraḥ.
F: iti madhyamādhikāraḥ samāptaḥ.
G: iti laghumānase madhyamādhikāraḥ.
H_1: iti laghumānase madhyamādhikāraḥ dvitīyaḥ.

ATHA SPHUṬAGATYADHIKARAḤ TṚTĪYAḤ

(Kendrotpannabhujākoṭyoḥ dhanarṇapratipādanam)

1. Grahassvocconitaḥ kendraṃ tadūrdhvādhordhajo bhujaḥ ।
Dhanarṇaṃ padaśaḥ koṭirdhanarṇadhanātmikā ॥ (11)

(Bhujākoṭī-tatkāṣṭhayorjyānayanam)

2. Oje pade gataiṣyābhyāṃ bāhukoṭī same'nyathā ।
Catustryaikaghnarāśyaikyaṃ doḥkoṭyoraṃśakāḥ kalāḥ ॥ (12)

(Sūryādigrahāṇāṃ mandacchedāḥ)

3. Sūryāt jināśvino (224) 'gāṅkā (97)-
śśaravedāḥ (45) khakhendavaḥ(100) ।
Dvyaṅkāḥ (92) khadantā(320)strirasā (63)-
śchedāḥ koṭyardhasaṃskṛtāḥ ॥ (13)

Apparatus

1b. D_1: ṣaḍū°. D_2: tadū°. G H_1 H_2: ṣaḍbhordhvādho bhavedbhujaḥ.

2b. G: bhujakotī in place of bāhukoṭī.

2d. B C F: bāhukoṭyoḥ kalāṃśakāḥ. G: catustryaikaiśca 4, 3, 1 rāśyaikyaṃ kṛtvā bhāgā dvisaṅguṇāḥ. H_1: catustrikughna°.

Note. After vs. 12, A_1 adds the following two verses, of which the first one is ascribed by the commentator Yallaya to Mallikārjuna Sūri and the second one to some anonymous author.
Gataiṣyakhaṇḍayogārdhamantarārdhena saṅguṇāt ।
Bhāgādeḥ khāgnilabdhonaṃ bhogyajyā mānase sphuṭāḥ ॥
Jīvāssāṅghryabdhi-sārdhāgni-dvyaṃśā liptāstu tāḥ sphuṭāḥ ।
Bhuktārdhāṃśonita-bhuktāṃśa-bhuktāṃśadviguṇonitāḥ ॥
The first one of these two verses occurs also in H_1.

3a. A_1 D_1 E F: chedā in place of sūryāt.

3c. A_1: °tāgnirasā°. G: khadantā 320 stryaṅgāṇi 63 chedāḥ.

Adoption

Vss. 11-12 (a-b) have been adopted without any alteration in the Karaṇāmṛta of Citrabhānu. See KA, i. 22.

(Grahāṇāṃ mandaphalānayanam)

4. Bhujo liptīkṛtaśchedabhakto grahaphalāṃśakāḥ ।

(Grahāṇāṃ mandasphuṭagatyānayanam)

Koṭirgatighnī chedāptā vyastaṃ gatikalāphalam ॥ (14)

(Grahāṇāṃ śīghracchadānayanam)

5. Kujajīvaśanicchedā
yugāgnyaga(4, 3, 7)hatā hṛtāḥ) ।
Tithiśailartu(15, 7, 6)bhirvyāsā
mūrcchaneśā (21, 11) jñaśukrayoḥ ॥ (15)

6. Te dostryaṃśayutāśśīghracchedāssyuḥ koṭisaṃskṛtāḥ ।

(Grahaśīghroccanirṇayaḥ)

Tārāgrahārkayośśīghraśśīghroccamitaro grahaḥ ॥ (16)

Apparatus

4 (a-b). G: liptikṛto bhaktaśchedai°.

4c. C: °gatighnā cchedāptaṃ. F: gatighnā chedāptā.

Note 1. After vs. 13, A_1 adds the following verses:

Chedā jināśvino'gāṅkā ravīndossphuṭakarmaṇi ।
Gatisphuṭārthamarkendvośchedau tāveva mānase ॥
Koṭyardhasaṃskṛtau chedau ravīndvorbimbasādhane ।

which Yallaya ascribes to Mallikārjuna Sūri. These verses occur also in H_1 and H_2. Between the second and third hemistitches, A_1 inserts the following verse:

Dviguṇasphuṭaliptighnabhujākoṭilavādikaḥ ।
Ṣaṣṭyuddhṛtādhaḥ prakṣepe doḥkoṭijyā lavādikāḥ ॥

which occurs in the midst of Yallaya's commentary on vss. 11-12 in D_1 but not in D_2. The second and third hemistitches with their order interchanged occur also in E in the commentary on vs. 13.

2. In E, verses 13 and 14 are interchanged.

4d. C: gatikalāḥ phalam.

Adoption

Vs. 14 (c-d) has been adopted verbatim in the Karaṇāmṛta of Citrabhānu. See KA, i. 27½ (a-b).

Vs. 16 (c-d) has been adopted without any alteration in the Karaṇāmṛta of Citrabhānu. See KA, i. 20½ (a-b).

Testimonia

Vs. 16 (c-d) has been quoted by Yallaya in his com. on SūSi, i. 25-27.

(Grahāṇāṃ mandasphuṭagatīnāṃ śīghrasphuṭīkaraṇam)

7. Vyāsaṃ śīghraphalārkāṃ(12)śabhāgonaṃ grahaśīghrayoḥ |
Gatyantaraghnaṃ chedāptaṃ tyaktvā śīghragatergatiḥ || (17)

Iti laghumānase sphuṭagatyadhikārastṛtīyaḥ.

Apparatus

7 (a-b). D_1 E: śīghraphalāṃśārkabhāgonaṃ.

Colophon. A_1: iti laghumānase sphuṭagatyadhikāraḥ tṛtīyaḥ.
B: No colophon but sphuṭagatyadhikāra ends here.
C: iti sphuṭagatyadhikāraḥ.
D_1 E G H_1: No colophon as no chapter ends here.
D_2 H_2: The mss. are broken at this place.
F: iti sphuṭādhikārassamāptaḥ.

ATHA PRAKĪRṆAKĀDHIKĀRAḤ CATURTHAḤ

(Grahaṇasamāgamādīnām gaṇitavedhasāmyartham candrasya tadbhukteśca dvitīyakarma)

1. Indūcconārkakoṭighnā gatyaṃśā vibhavā (11) vidhoḥ ।
Guṇo vyarkendudoḥkoṭyo rūpa(1)pañcā(5)ptayoḥ kramāt ॥ (18)

2. Phale śaśāṅkatadgatyorliptādye svarṇayorbadhe ।
Ṛṇaṃ candre dhanaṃ bhuktau svarṇasāmyabadhe'nyathā ॥ (19)

(Deśāntarasaṃskāraḥ)

3. Avantīsamayāmyodagrekhāpūrvāparādhvanā ।
Grahagatyaṃśaṣaṣṭyaṃśo hato liptāsvṛṇaṃ dhanam ॥ (20)

(Tithi-karaṇanakṣatra-yogānayanam)

4. Vyarkendostithitithyardhe grahādbhānyanupātataḥ ।
Yogāscandrārkasaṃyogāttadādyantau svabhuktitaḥ ॥ (21)

Iti laghumānase prakīrṇakādhikāraḥ caturthaḥ.

Apparatus
b. D_1: °liptādyaṃ.
3a. A_1 C D_1 H_1 H_2: Avanti°.
3 (c-d). A_1 F: °ṭyaṃśā hatā liptā ṛṇaṃ dhanam.
D_1 D_2 H_1: hatā bhuktiḥ khakhāṣṭābdhihṛtā liptāstvṛṇaṃ dhanam.
G: liptā ṛṇaṃ dhanam.
4c. A_1: °candrārkasaṃyogasta°.
Colophon. A_1: iti mānasakaraṇe prakīrṇādhikāraḥ caturthaḥ.
B: iti prathamo'dhyāyaḥ. (The present prakīrṇakādhikāra also ends here.)
C: iti prakīrṇakādhikāraḥ. iti prathamo'dhyāyaḥ.
D_1 D_2: iti. ... grahasphuṭādhikāro dvitīyaḥ.
E: iti sphuṭīkaraṇādhyāyaḥ. (Vss. 20 and 21 are missing from E.)
F: iti laghumānase prathamādhyāyagaṇitaṃ sampūrṇam.
G: iti tithyadhikāraḥ.
H_1: iti laghumānase prakīrṇakādhikāra(stṛtīyaḥ).
H_2: The manuscript is broken at this place.

Adoption
Vs. 21 has been adopted by Acyuta after making some alteration in the second half. See KU, ii. 13.

Note. After vs. 21, A_1 adds the following verse:
Nakhācalaiḥ khakhagajaiḥ khakhebhaiḥ khāṅgavahnibhiḥ ।
Tithyarkṣayogakaraṇā dyumānārdhādgataiṣyakam ॥

ATHA TRIPRAŚNĀDHIKĀRAḤ PAÑCAMAḤ

(Meṣādirāśināṃ caravināḍyānayanam)

1. Nakha(20)ghnā viṣuvacchāyā svākṣāṃ(5)śonā tri(3)bhājitā ।
Udagviṣuvadādyarkabhujarāśiguṇāścare ॥ (22)

(Meṣādirāśīnāmudayavināḍikānayanam)

2. Vasubhā(278)nyaṅkagodasrā (299) stridantā(323)śca kramotkramāt ।
Tattaccaraguṇārdhonā madhyaṣaṭke'nyathodayāḥ ॥ (23)

(Iṣṭaghaṭikābhyo lagnānayanaṃ iṣṭalagnādghaṭikānayanañca)

3. Svodayaiḥ praśnanāḍībhirvardhito'rko'nupātataḥ ।
Lagnaṃ tadvadvivṛddhe'rke lagnatulye tu nāḍikāḥ ॥ (24)

(Dinamānasādhanam)

4. Vyastaṃ caravināḍībhiḥ khāgnaya(30)ssaṃskṛtā dinam ।

(Natanāḍyānayanam)

Maddhyānnatanāḍyassyurdinārdhadyugatāntaram ॥ (25)

(Madhyāhnacchāyānayanam)

5. Pañca(5)ghneṣṭacarārdhena palabhāptena saṃskṛtāt ।
Ādyāccaraguṇādahnā digūnena dinārdhabhā ॥ (26)

(Iṣṭacchāyānayanam)

6. Vidigdinanavābhyāsānnatakṛtyaṃśako yutaḥ ।
Vidigdinaśatāṃśena guṇo'sau vyekako haraḥ ॥ (27)

Apparatus
1a. A_1 G H_2: nakhaghnī. H_1: viṣuvacchāyā 3-30
1c. A_1: °dādyarke.
1d. G: guṇaścaraṃ.
2c. A_1 E G: tadvaccara°.

Note 1. D_1 puts vs. 25 between vss. 22 and 23.
2. E breaks off after vs. 23 in the midst of its commentary.
3. D_2 breaks off after vs. 24 in the midst of commentary on it.
4. Cf. vs. 24 with KK, iii. 5.

4d. A_1 G: °rdhāddyugatā°. D_1 E put vs. 25 between vss. 22 and 23.
6 (a-b). D_1 F: vidigdinānnavābhyastānnata°.

Adoption
vs. 25 has been adopted without any alteration in the Karaṇāmṛta of Citrabhānu. See KA, ii, 1.

Testimonia
Vs. 25 (a-b) has been quoted by Yallaya in his commentary on SūSi, ii. 60-61.

7. Tadaikyācchaṅku(12)vargaghnānmadhyacchāyāguṇāhateḥ ।
Kṛtyā yutātpadaṃ yatsyāttasmācchedāptamiṣṭabhā ॥ (28)

(Chāyātaḥ chāyākarṇānayanaṃ tasmācchāyā ca)

8. Chāyārka(12)vargasaṃyogānmūlaṃ karṇastato'pi bhā ।

(Iṣṭacchāyāmadhyāhnacchāyābhyāṃ nataghaṭikāsādhanam)

Iṣṭakarṇaḥ svamadhyāhnakarṇāntarahṛto guṇaḥ ॥ (29)

9. Vidigdinaśatāṃ (100)śonaguṇakena vidigdināt ।
Navāhatāt phalaṃ yatsyāt tanmūlaṃ natanāḍikāḥ// (30)

Iti laghumānase tripraśnādhikāraḥ pañcamaḥ.

Apparatus
8b. A_1 G: tato vibhā.
8 (c-d). B C: Iṣṭaḥ karṇaḥ. G: svamadhyāhnakarṇonavihṛto guṇaḥ.
9. After vs. 30, G adds the following verse:
Śāke vedaguṇābdhyūna(434)śeṣe ṣaṣṭivibhājite ।
Ayanāṃśāḥ pradātavyā ravau lagnadyumānayoḥ ॥

Colophon. A_1: iti mānasakaraṇe tripraśnādhikāraḥ pañcamaḥ.
B: iti .... tripraśnādhyāyaḥ dvitīyaḥ.
C: iti ... dvitīyo'dhyāyaḥ.
D_1: iti .... tripraśnādhikārastṛtīyaḥ.
F: iti chāyādhikārassamāptaḥ.
G_1: iti laghumānase tripraśnādhikāraḥ.
H_1: iti laghumānase chāyālagnādikāraścaturthaḥ.
H_2: The manuscript is broken at this place.

ATHA GRAHAYUTIGRAHAṆADVAYAPARILEKHANĀDHIKĀRAḤ ṢAṢṬHAḤ

(Grahayoryogasya gataiṣyajñānam)

1. Grahayorantare svalpe'nalpabhukteḥ purassaraḥ।
Yadā'lpagatireṣyassyāttadā yogo'nyathā gataḥ ॥ (31)

(Grahayossamāgamakālajñānam)

2. Yutyā bhinnadiśorgatyorantaraikadikkayoḥ ।
Grahāntaradināni syustaissamāvanupātataḥ ॥ (32)

(Sūryācandramasorbimbānayanam)

3. Bhānorbimbaṃ ravicchedahṛtāḥ khakhakṛtācalāḥ (400) ।
Śaśinaḥ khakhabhūrāmā(3100)ścandramāndaharoddhṛtāḥ ॥ (33)

(Candramārge chāyāgrahamānānayanam)

4. Chāyāgrahassaṣaḍbho'rkastanmaṇḍalakalāmitiḥ ।
Candramārge śaśicchedahṛtāḥ khakhaguṇoragāḥ (8300) ॥ (34)

(Bhaumādīnāṃ bimbamānānayanam)

5. Aṅgānīśā (6, 11) nakhāssūryā (20, 12)
dviyamā (2, 2) daśatāḍitāḥ ।
Svaśīghracchedadig(10)yoga-
hṛtā bimbāni bhūsutāt ॥ (35)

Apparatus
2c. B C: grahāntarād.
3a. C: bhānorbimbā.
3d. B C F G: ° mandaharo°.

5. After vs. 35, C gives the following verse and explain it but notes that, according to some, it is interpolatory:
Kṛtanetrabhujaṅgāṅgadiśo daśahatāḥ kramāt ।
Pātabhāgāḥ kujādīnāṃ pātakṣepau na bhāsvataḥ ॥
G has the following equivalent verse:
Kṛtā yamāśca vasavaḥ ṣaṭ diśo daśasaṃguṇāḥ ।
Krameṇa bhūsutādīnāṃ pātāṃśāḥ parikīrtitāḥ ॥
It is interesting to note that the following verse which is practically the same as the former one occurs in the Karaṇāmṛta of Citrabhānu:
Kṛtanetrabhujaṅgāṅgadiśo daśaguṇāḥ kramāt ।
Pātabhāgāḥ kujān mandasphuṭāt pātāṃśavarjitāt ॥
See KA, iv. 1.
Adoption
Vss. 31-32 have been adopted in the Karaṇāmṛta of Citrabhānu with grahāntarāddināni in place of grahāntaradināni in vs. 32c. See KA, iii. 2(c-d) 3½. Vss. 31-32 have also been adopted by Acyuta without making any significant alteration. See KU, iv. 1-2.

(Candrādīnāṃ vikṣepānayanam)

6. Mandasphuṭātsvapātonād grahācchīghrājjñaśukrayoḥ ।
Bhujāḥ ṣaṭkṛti(36)sūryāṣṭi (12,16) navāṣṭyaṣṭi(9, 16, 16)hṛtāh kramāt ॥ (36)

7. Candrād vikṣepaliptāssyustāḥ kujādvyāsatāḍitāḥ ।
Śīghracchedahṛtāsspaṣṭāssvarṇākhyā dakṣinottarāh ॥ (37)

(Yutikālikabimbāntaraṃ bhedayuddhasamprāptiśca)

8. Vikṣepayossamadiśorantaraṃ bhinnayoryutiḥ ।
Bimbāntaraṃ laghunyasmin bhedo mānārdhayogataḥ ॥ (38)

(Bhedayuddha sūryagrahaṇe ca lambanānayanam)

9. Grahonalagnamakṣa(5)ghnaṃ lambanadyugataṃ yutau ।
Lambanaṃ dvyakṣakarṇāptaṃ natonāhataviṃśateḥ ॥ (39)

Apparatus

8. After vs. 38, A_1 gives the following verse:
Saumyakṣepo'dhiko jetā hīnakṣepaśca dakṣiṇe ।
Ubhayorekamārgaśced bhinnamārge jayottaraḥ ॥
D_1 too gives this vs. and explains it also, but introducing this verse, Yallaya says:
Ācāryeṇāpi yuddhyadgrahajayāpajayalakṣaṇaṃ kiñciduktam.
So, according to Yallaya, this vs. belongs to Mañjula.
F breaks off after commentary on vs. 38.
G ends this chapter after vs. 38 with the colophon: Iti laghumānase grahayutyadhikāraḥ.

9a. B C G: grahonaṃ lagna°. H_2: grahonalagnaṃ pañcaghnaṃ.

9b. A_1: nataṃ in place of yutau, but yutau is explained in the com.
Between vss. 39(a-b) and 39(c-d), A_1 inserts the following verse (without explaining it):
Bhāgādidviguṇaṃ kāryaṃ lambanadyugataṃ bhavet ।
Lambanadyugatāt pañca-pañcabhirnatasādhanam ॥
C inserts the following vs. (giving some explanation also):
Lambanadyugatāt pañcadaśabhirnatasādhanam ।
Dinārdhena nataṃ sādhyaṃ lambanasphuṭaparvaṇah ॥
This vs. occurs in H_1 also at the same place. Yallaya ascribes this vs. to his teacher Sūryācārya. The first half of this vs. occurs in SiSaṃ (iv. 9c-d) also. See Appendix 4.

Testimonia

Vs. 36 (a-b) has been quoted by Yallaya in his com. on SūSi, ii. 54.

(Khārkānayanam)

10. Prākpaścāllambanenonayuktaṃ dinagataṃ sphuṭam ।
Tannatākṣāṃ(5)śahīnaḥ prāk sūryaḥ khārko'nyathā yutaḥ ॥ (40)

(Natyānayanam)

11. Tadiṣṭacaraṣaḍ(6)ghātapalabhāptena saṃskṛtāt ।
Palabhonāhatāt khākṣād (50) dvi(2)ghnāttattvai(25)rhṛtā natiḥ ॥ (41)

(Spaṣṭavikṣepānayanaṃ chādyachādakagrahaparijñānañca)

12. Tātkālikenduvikṣepo yukto natyaikadikkayā ।
Hīno'nyathā yutau spaṣṭaśchādako'dhaḥsthito grahaḥ ॥ (42)

(Madhyasthityardhānayanam)

13. Bimbāntarakṛtiṃ projjhya mānaikyārdhakṛteḥ padam ।
Ṣaṣṭighnaṃ samadiggatyorantarāptaṃ sthiterdalam ॥ (43)

(Sparśamokṣasthityardhānayanam)

14. Sthityardhe candravikṣepakṛtendrā(144)ṃśayutonite ।
Spaṣṭe spārśikamūnaṃ syādyugvikṣepe'nyathā mahat ॥ (44)

(Arkagrahaṇe sparśamokṣakālasādhanam)

15. Tadūnayutamāsāntadyugate kṛtalambane ।
Sparśo mokṣo bhaved bhānorna lagnādinduparvaṇi ॥ (45)

Apparatus
10b G: °yutaṃ in place of °yuktaṃ.
Between 40 (a-b) and 40 (c-d), A_1 inserts:
Dinārdhena nataṃ sādhyaṃ lambanaṃ sphuṭaparvaṇaḥ ।
11b. G: saṃskṛtāḥ.
11 (c-d). G: palabhonāhatāḥ khāskāḥ dvighnāstattvahṛtā natiḥ.
12. G ends this chapter after vs. 42 with the colophon:
Iti laghumānase sūryagrahaṇādhikāraḥ ।
14 (a-b). G: Sthityardhaṃ candravikṣepakṛtendrāṃśayutonitam.
14 (c-d). C: syād dyuvikṣepe.
15a. C: tadūnayukta°.
15c. B C: sparśamoksau.
Adoption
Vs. 44 has been adopted without any alteration in the Karaṇāmṛta of Citrabhānu. See KA, iii. 16½. Vs. 45 occurs in Karaṇāmṛta (iii. 16½) in the form:
Tadūnayutamāsāntadyugate lambane kṛte ।
Sparśamokṣau raveḥ syātāṃ na lambanāvanatī vidhoḥ ॥
Testimonia
Vs. 42d has been quoted by Raghunātharāja in his com. on Ā, iv.

(Akṣavalanānayanam)

16. Yutimadhyanatābhyastā palabhā bhānu(12)bhājitā ।
Prāgudagdakṣiṇaṃ paścādvalanaṃ ravimaṇḍale ॥ (46)

(Ayanavalana-pāramārthikavalanayorānayanam)

17. Graheṇāyanayoralpamantaraṃ dvighnamāyanam ।
Valanaṃ syāttayoryogaviśleṣāt pāramārthikam ॥ (47)

(Parilekhavidhiḥ)

18. Ṣaḍakṣāṃ(56)gulayaṣṭyagre dṛṅmadhyādaṃśakoṅgulam ।
Digvṛttaparidhau prācī valanāgre tato'parā ॥ (48)

19. Tatpūrvāpararekhāto vikṣepāntaritā parā ।
Rekhā mandagatermārgastadvacchīghragaterapi ॥ (49)

20. Vṛttamadhyādyathāyātavikṣepādgrahamadhyayoḥ ।
Grahayoryutimadhyaṃ syāt tato'nyatra grahāntarāt ॥ (50)

Iti laghumānase grahayutigrahaṇadvayaparilekhanādhikāraḥ ṣaṣṭhaḥ.

Apparatus
16d. B C G: radamaṇḍale.
17a. C: grahaṇāyana°.
17d. C: viyogāt in place of viśleṣāt.
18b. B: °daṃśatongu°.
19b . B: 'parā.
20 (a-b). C: °d yathāyâvad vikṣepairgraha°. D_1: °yātā vikṣepa°.
Colophon. A_1: iti grahayutigrahaṇadvayaparilekhanādhikāraḥ ṣaṣṭhaḥ.
B: iti .... grahaṇādhyāyastṛtīyaḥ.
C: iti ... grahaṇādhyāyastṛtīyaḥ.
D_1: iti .... grahaṇadvayayutiparilekhanādhyāyaścaturthaḥ.
G: iti laghumānase candragrahaṇādhikāraḥ.
H_1: iti laghumānase grahayuddhagrahādhikāraḥ pañcamo'dhyāyaḥ.

Testimonia
Vss. 48 (c-d), with tadvṛttaparidhau in place of digvṛttaparidhau, and 49 (c-d) have been quoted by Yallaya in his com. on SūSi, viii, 16-18 (a-b). And vss. 48 (c-d)-49, without any alteration, have been quoted by Tamma Yajvā in his com. on SūSi, vii. 18.

ATHA GRAHODAYĀSTAMAYĀDHIKĀRAḤ SAPTAMAḤ

(Akṣadṛkkarmākhyasaṃskāraḥ)

1. Tithi(15)ghnāccarasaṃskārāt svodayenāṃśakādikam ।
Svarṇaṃ kṣepavaśāt kāryaṃ grahe ṣaḍbhayute'nyathā ॥ (51)

(Ayanadṛkkarmākhyasaṃskāraḥ)

2. Grahasyotkramakoṭighnāt kṣepābdhyaṃ(4)śāt svalagnahṛt ।
Kṣepakoṭyossamānyatve svarṇaṃ bhāgādyanukramāt ॥ (52)

(Grahāṇāmastārkānayanam)

3. Sūryāṣṭiviśvarudrāṣṭa-
tithyaṃśa(12, 16, 13, 11, 8, 15)ghnaiḥ khakhāgnibhiḥ (300) ।
Prāgbhodayāptairyuktonas-
sūryo'stārkaśśaśāṅkataḥ ॥ (53)

(Astagasya grahasya lakṣaṇam)

3′. Vikṣepo bhinnatulyāśo valanaghnaḥ khakhaṅka(900)kaiḥ ।
Hṛto'ṃśāstairyutonassan graho'stārkāntare'stagaḥ ॥ (53)

(Agastyasyodayāstajñānam)

4. Agastyasyāstodayārkāṃśāssaptaśailā(77)ssvarāṅkakāḥ(97) ।
Aṣṭa(8)ghnaviṣuvacchāyāhīnayuktāssvadeśajāḥ ॥ (54)

(Sphuṭacarasaṃskāraḥ)

5. Caratānāṃ(49)śaṣaḍvarga(36)viśleśeṅākṣabhāhatāt ।
Svavikṣepādavāptena svacaraṃ saṃskṛtaṃ sphuṭam ॥ (55)

Iti laghumānase grahodayāstamayādhikāraḥ saptamaḥ.

Apparatus
1. Occurs in A_1 B C only; missing from D, G.
1 (a-b). A_1: tithighna° °nāṃśakādikāḥ.
2. Occurs in A_1 B C only; missing from D_1 G.
2b. B C: svalagnabhāt.
2d. B C: bhāgādyapi kramāt.
3′. Occurs in A_1 C D_1 G only; missing from B. Although it occurs in A_1, Praśastidhara does not comment on it.
3′ a. C: ° tulyāśāvalanaghnaḥ.
3′ (c-d). G: ′ ryutonassyāt sa graho°.
4d. B C: hīnā yuktāḥ.
G adds after vs. 54 the colophon: Udayāstādhikāraḥ.
Colophon. A_1: iti laghumānase grahodayāstādhikārassaptamaḥ.
D_1: iti ... grahodayāstādhikāraḥ pañcamaḥ.
G: iti laghumānase carasaṃskāraḥ.

ATHA MAHĀPĀTĀDHIKĀRAḤ AṢṬAMAḤ

(Pātasthitikālaparijñānam)

1. Antare'rkendudinayorvināḍyaḥ palabhālpikāḥ ।
Yāvattāvad vyatīpāto vaidhṛtastaddivāniśoḥ ॥ (56)

Iti laghumānase mahāpātādhikāro'ṣṭmaḥ.

ATHA CANDRAŚṚṄGONNATYADHIKĀRO NAVAMAḤ

(Candracchāyānayanam)

1. Vihitodayadṛkkarma tatkālenduvilagnataḥ ।
Śaśāṅkadyugataṃ tasmāt taddināccārkavatprabhā ॥ (57)

(Sitāsitamānānayanam)

2. Dvyū(2)nāḥ pakṣādtithyardhāssasvāgāṃ(7)śassitāsite ।

(Śṛṅgonnatiparilekhopayogisphuṭavalanāyanam)

Vikṣepavyomadhṛtyaṃ(180)śasaṃskṛtaṃ valanaṃ sphuṭam ॥ (58)

Apparatus
1d. B C: vaidhṛtastu divāniśoḥ. G: vaidhṛtaśca divāniśoḥ.
Colophon: D_1: iti .... mahāpātādhikāraḥ ṣaṣṭhaḥ.

Adoption
Vs. 56 has been adopted without any alteration in the Karaṇāmṛta of Citrabhānu. See KA, ii. 24-24½.

Testimonia
Vs. 56 has been quoted by Yallaya in his com. on SūSi, ii. 60-61.

Apparatus
1a. C: vihitobhayadṛkkarma.
1b. G: °vilagnayoḥ.
1 (c-d). Missing from G.
1d. B C D: °nādarkavatprabhā.
After vs. 57, D_1 adds the colophon: iti ... candracchāyādhikāraḥ saptamaḥ and G adds the colophon: candraprabhānayanam.
2c. C: vikṣepād.
In D_1 and G, vs. 58 occurs after vs. 58'.
After vs. 58, G adds the colophon: śuklakṛṣānayanam.

(Sṛṅgonnatiparilekhanopayogi-chedānayanam)

2′. Pakṣādatītatithyardhatithya(15)ntarahṛto'dhikaḥ ।
Nṛpa(16)vargo'rdhitacchedaṃ śuklāntādvidhumaṇḍale ॥ (58′)

(Śṛṅgonnatiparilekhanavidhiḥ)

3. Bimbāparadiśo bhāgāt prāgvṛddhiśśuklakṛṣṇayoḥ ।
Śuklāntādbimbamadhyaspṛkchedāgrācchedanaṃ chidā ॥ (59)

(Granthopasaṃhāraḥ)

4. Mānasākhyaṃ grahajñānaṃ ślokaṣaṣṭyā mayā kṛtam ।
Bhavantyapayaśobhājaḥ pratikañcukakāriṇaḥ ॥ (60)

Iti laghumānase candraśṛṅgonnatyadhikāro navamaḥ.

Samāpto'yaṃ granthaḥ.

Apparatus

2′. Occurs in A_1 D only; missing from B C G.

2′a. G: pakṣādvyatīta°.

2′d. G: śuklāntādradamaṇḍale.

3(c-d). B C D_1: °chedāgracchedanaṃ.
G: śuklāntānmadhyabimbasya chedayo chedanaṃ chidā.

4a. D_1: mānasākhyagrahajñānaṃ.

4c. B: bhavantyatrā'yaśobhājaḥ.
C: bhavantyato'yaśobhājaḥ or bhavantyato'yaśobhāgāḥ.
G: bhavantyastādyaśobhājaḥ.

Colophon:

A_1: iti ... mahāpātenduršṛgonnatyadhikāro'ṣṭamaḥ.

B: iti ... grahodayāstamayādhikāraścaturthaḥ.

C: iti ... saṃkīrṇādhikāraścaturtho'dhyāyaśca samāptaḥ.

D_1: iti ... candraśṛṅgonnatyadhikāro'ṣṭamaḥ.

G: iti muñjālabhaṭṭaviracite laghumānasākhye karaṇe śṛṅgonnatyadhikāraḥ.

APPENDIX 1

CONCORDANCE OF VERSES OF THE VARIOUS MANUSCRIPTS

Verses of the edited text	Verses of Mss. A_1, B, C	Verses of Ms. D_1	Verses of Ms. E	Verses of Ms. G
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9
10	10	10	10	10
11	11	12	11	11
12	12	13	12	12
13	13	14	14	13
14	14	15	13	14
15	15	16	15	15
16	16	17	16	16
17	17	18	17	17
18	18	19	18	18
19	19	20	19	19
20	20	11	—	20
21	21	21	—	21
22	22	22	20	22
23	23	24	22	23
24	24	25	—	24
25	25	23	21	25
26	26	26	—	26
27	27	27	—	27
28	28	28	—	28
29	29	29	—	29
30	30	30	—	30
31	31	31	—	31
32	32	32	—	32
33	33	33	—	33
34	34	34	—	34
35	35	35	—	35
36	36	36	—	36
37	37	37	—	37

Verses of the edited text	Verses of Mss. A_1, B, C	Verses of Ms. D_1	Verses of Ms. E	Verses of Ms. G
38	38	38	—	38
39	39	39	—	39
40	40	40	—	40
41	41	41	—	41
42	42	42	—	42
43	43	43	—	43
44	44	44	—	44
45	45	45	—	45
46	46	46	—	46
47	47	47	—	47
48	48	48	—	48
49	49	49	—	49
50	50	50	—	50
51	51	—	—	—
52	52	—	—	—
53	53	51	—	51
53′	—	52	—	52
54	54	53	—	53
55	55	54	—	54
56	56	55	—	55
57	57	56	—	56
58	58	58	—	58
58′	—	57	—	57
59	59	59	—	59
60	60	60	—	60

APPENDIX 2

ARRANGEMENT OF VERSES IN THE VARIOUS MANUSCRIPTS

1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9
10	10	10	10	10
11	11	20	11	11
12	12	11	12	12
13	13	12	14	13
14	14	13	13	14
15	15	14	15	15

16	16	15	16	16
17	17	16	17	17
18	18	17	18	18
19	19	18	19	19
20	20	19	22	20
21	21	21	25	21
22	22	22	23	22
23	23	25	—	23
24	24	23	—	24
25	25	24	—	25
26	26	26	—	26
27	27	27	—	27
28	28	28	—	28
29	29	29	—	29
30	30	30	—	30
31	31	31	—	31
32	32	32	—	32
33	33	33	—	33
34	34	34	—	34
35	35	35	—	35
36	36	36	—	36
37	37	37	—	37
38	38	38	—	38
39	39	39	—	39
40	40	40	—	40
41	41	41	—	41
42	42	42	—	42
43	43	43	—	43
44	44	44	—	44
45	45	45	—	45
46	46	46	—	46
47	47	47	—	47
48	48	48	—	48
49	49	49	—	49
50	50	50	—	50
51	51	53	—	53
52	52	53′	—	53′
53	53	54	—	54
53′	—	—	—	—
54	54	55	—	55
55	55	56	—	56
56	56	57	—	57
57	57	58′	—	58′
58	58	58	—	58
58′	—	—	—	—
59	59	59	—	59
60	60	60	—	60

APPENDIX 3

VERSES OF LAGHUMĀNASA ADOPTED IN LATER WORKS

A. Verses adopted by Bhojarāja (A.D. 1042)

The following verses have been adopted without or with some alteration in the Rājamṛgāṅka of Bhojarāja. Bhojarāja (generally known as Bhoja) was the Paramāra Mahārājā who ruled from Dhārā[1] from about A.D. 1005 to about A.D. 1055. He was a great patron of Sanskrit learning and a number of works are ascribed to his authorship.

(1) LMā, vs. 43.
This has been adopted without alteration. See RāMṛ, viii. 23.

(2) LMā, vs. 45.
Compare this vs. with RāMṛ, viii. 25:
Tadūnayuksamakaladyugate kṛtalambane ।
Sparśamokṣādikau kālau jāyete prasphuṭau ca tau ॥

(3) LMā, vs. 46.
Compare this vs. with RāMṛ, viii. 27:
Sparśādijanatābhyastā palabhā bhānubhājitā ।
Prāgudag dakṣiṇaṃ paścāt valanaṃ radamaṇḍale ॥

(4) LMā, vs. 47
Compare this verse with RāMṛ, viii. 28:
Grāhyenāyanayoralpamantaraṃ dvighnamāyanam ।
Valanaṃ syāttayoryogaviyogāt paramārthikam ॥

B. Verses adopted by Citrabhānu (A.D. 1530)

The following verses of the Laghumānasa have been adopted without any alteration in the Karaṇāmṛta of Citrabhānu. Citrabhānu Nampūtiri of Gautama Gotra belonged to the village Covvaram (Skt. Śivapura) near Trichur in Kerala State. He was a pupil of Nīlakaṇṭha Somayāji (c. A.D. 1500) and wrote his Karaṇāmṛta in A.D. 1530.

(1) LMā, vss. 11-12 (a-b).
KA, i. 22 is exactly the same.
(2) LMā, vs. 14 (c-d).
KA, i. 27½ (a-b) is exactly the same.
(3) LMā, vs. 16 (c-d).
KA, i. 20½ (a-b) is exactly the same.

[1] The town called Dhārā or Dhāra exists in Dhāra district which is to the south-west of Ujjain district in Madhya Pradesh.

(4) LMā, vs. 25.
KA, ii. 1 is exactly the same.
(5) LMā, vss. 31-32.
KA, iii. 2 (c-d)-3½ is exactly the same.
(6) LMā, vs. 44.
KA, iii. 16½ is exactly the same.
(7) LMā, vs. 56.
KA, ii. 24-24½ is exactly the same.

The following verses have been adopted there after suitable modification:

(8) LMā, vs. 2′.
Compare this verse with KA, i. 19½:
Svararavayaḥ khākṛtayo dvinagabhuvo'śītirabhrajināḥ ।
Bhaumānmandoccāṃśā vasuturagā bhāskarasyāpi ।।
(9) LMā, vs. 45.
Compare this verse with KA, iii. 17½:
Tadūnayutamāsāntadyugate lambane kṛte ।
Sparśamokṣau raveḥ syātāṃ na lambanāvanatī vidhoh। ।।

C. Verses adopted by Acyuta (d. A.D. 1621)

The following verses of the Laghumānasa have been adopted with or without any alteration by Acyuta in his Karaṇottama. Acyuta, like Citrabhānu, hails from Kerala State. He lived in the village Tṛkkaṇṭiyūr (Skt. Śrī Kuṇḍapura) situated near Tirur in Calicut district in South Malabar, and was a pupil of Jyeṣṭhadeva (A.D. 1500-1610). He wrote a number of works and died in A.D. 1621.

(1) LMā, vss. 31-32.
These verses have been adopted by Acyuta without making any significant alteration. Acyuta's version is:
Grahayorantare svalpe'nalpabhukteḥ puraḥsaraḥ ।
Yadālpagatireṣyassyāt tadā yogo'nyathā gataḥ ।।
Yuktyā bhinnadiśorgatyorantareṇaikadikkayoḥ ।
Grahāntarād dināyāḥ syustaissamāvanupātataḥ ।। (KU, iv. 1-2)

(2) LMā, vs. 21.
This verse has been adopted by Acyuta after making some alteration in the second half. He states this verse in the following form:
Vyarkendostithitithyardhe grahāddhānyanupātataḥ ।
Viṣkambhādyā ravīndvaikyāt tadādyantau svabhuktitaḥ ।। (KU, ii. 13)

APPENDIX 4

RULES INVENTED BY MAÑJULA IN LATER WORKS

1. LMā, vs. 18-19: Rule for a special lunar correction.

This rule is found to occur exactly in the same form in the Karaṇa-kamala-mārtaṇḍa of Daśabala (A.D. 1058). Daśabala states it as follows:

Satribhendūccahīnārkadorjyā candragaterlavaiḥ ||
Vibhavaistāḍitā dvaidhā hatā vyarkaniśāpateḥ |
Bhujākoṭijīvābhyāmādyaṃ dhṛtibhavairbhajet ||
Dvitīyaṃ khābhraṣaḍvāṇaiḥ kalādye staḥ phale kramāt |
Yāminīnāthatadgatyoḥ kṣayasvaṃ svarṇayorhatau ||
Svarṇaṃ sāmyavadhe vyastaṃ śīghrakarma vidhoridam |
(KKM, ii. 46 (c-d)-49 (a-b))

2. LMā, vs. 26: Rule for midday shadow.

This rule is found to occur in the Siddhānta-saṃgraha of Vīrasūri (son of Koṭṭacenna), written in A.D. 1606. It is stated there as follows:

Iṣṭakālacarārdhaṃ tu bāṇaghnaṃ palabhāhṛtam |
Dhanarṇaṃ meṣajūkābhyāṃ sāyanārkavaśśādbhavet ||
Sadā ṛṇaṃ tvādyacaramṛṇaṃ sāmye tu yojayet |
Dhanarṇe vivaraṃ hāryaṃ dinaṃ digvarjitaṃ haraḥ ||
Tenāptamaṅgulādi syāt phalamiṣṭadinārdhabhā |
(SiSaṃ, iii. 10-12 (a-b))

3. LMā, vss. 27-28: Rule for instantaneous shadow.

This rule occurs in the Rājamṛgāṅka of Bhojarāja (A.D. 1042), the Siddhānta-saṃgraha, and the Grahagaṇita-bhāskara of Tamma Yajvā (A.D. 1613). It is stated there as follows:

(1) Dinamānaṃ vidik kṛtvā tataḥ kuryānnavāhatam |
Tatkālanatavargāptaṃ vidigdinaśatāṃśayuk ||
Vijñeyo guṇakaḥ so'tha vyeko hara iti smṛtaḥ |
Śaṅkuvargaguṇaṃ kuryādaikyaṃ guṇakahārayoḥ ||
Madhyabhāguṇakāghātavargayuktaṃ tu tadvadham |
Sādhayitvā'tha tanmūlaṃ hareṇa vibhajettataḥ ||
Aṅgulādyatra yallabdhaṃ seṣṭacchāyā bhavet sphuṭā |
(RāMṛ, iii, 19-22 (a-b))

(2) Digvarjitāharnandaghnaṃ natavargahṛtaṃ yutam |
Vidigdinaśatāṃśena guṇo vyeko haraḥ smṛtaḥ ||
Guṇo harayutaḥ śaṅkuvargaghno'tha dinārdhabhā |
Guṇaghnā vargitā pūrvayutā mūlaṃ haroddhṛtam ||
Aṅgulādiṣṭabhā
(SiSaṃ, iii. 16-18a)

(3) Digvarjitaṃdinamānaṃ goghnaṃ natavargakena vibhajya yaḥ ।
Digvarjitadinamānaśyatāṃśyukto guṇo bhavati ।
Ekonaśchedaḥ syācchedaguṇaikyācchaṅkuvargahatāt ।
Guṇaguṇitamadhyacchāyāvargaikyānmūlena yallabdham ॥
Tacchedakena vibhajedaṅgulipūrveṣṭakālikī chāyā ।
(GGB, iv. 8-10 (a-b))

4. LMā, vss. 29 (c-d)-30: Rule for Nata-kāla or hour-angle.
This rule too occurs in the Rājamṛgāṅka, the Siddhānta-saṃgraha, and the Grahagaṇita-bhāskara, as follows:

(1) Iṣṭakarṇo'ntarahṛta iṣṭamadhyāhnakarṇayoḥ ।
Digūnadyuśatāṃśena rahito bhājako bhavet ॥
Dinapramāṇādrahitād digbhirnavabhirāhatāt ।
Bhājakenātha yallabdhaṃ tatpadaṃ natanāḍikāḥ ॥
Tāśca madhyāhnataḥ śodhyā dinārdhaghaṭyo gatāgatāḥ ।
Iṣṭacchāyeṣṭakarṇābhyāmevaṃ samayasādhanam ॥
(RāMṛ, iii. 23-25)

(2) Iṣṭakarṇaḥ svamadhyāhnakarṇāntarahṛto guṇaḥ ।
Digvarjitadivāmānaśatāṃśarahito haraḥ ॥
Dinaṃ digvarjitaṃ nandanighnaṃ harahṛtaṃ padam ।
Prākpaścānnatanāḍyastāḥ śodhyā yojyā divādale ॥
(SiSaṃ, iii. 14-15)

(3) Dyudaleṣṭaśrutivivaraṃ yatsyāttteneṣṭakarṇako bhājyaḥ ॥
Guṇako daśahīnāddinamānācchatāṃśahīno harastena ।
Digvarjitadinamānaṃ goghnaṃ vibhajya tanmūlam ॥
Natanāḍyaḥ syuḥ dyudale hīnāḥ pūrvonnatanāḍyaḥ ।
(GGB, iv. 10 (c-d)-12 (a-b))

5. LMā, vss. 36-37: Rule for planet's latitude.
This rule occurs in the Karaṇāmṛta as follows:
Kṛtanetrabhujaṅgāṅgadiśo daśaguṇāḥ kramāt ।
Pātabhāgāḥ kujānmandasphuṭāt pātāṃśavarjitāt ॥
Jñabhṛgvoḥ kṛtamandātsvaśīghroccāddorguṇāttataḥ ।
Arkabhūpāṅkanṛpatipārthivairnihatātkramāt ॥
Svavyāsaghnāt svaśīghracchedoddhṛtāḥ kṣepaliptikāḥ ।
(KA, iv. 1-2½)

6. LMā, vs. 39: Rule for lambana or parallax in longitude.
This rule occurs in the Rājamṛgāṇka, the Gaṇakānanda of Sūryācārya (A.D. 1460), the Siddhānta-sāra of Mallaya Yajvā (A.D. 1596), and the Siddhānta-saṃgraha. It is stated there as follows:

(1) Tithyantakālikārkonaṃ tallagnaṃ pañcasaṅguṇam ǀ
Rāśayo ghaṭikā jñeyā dvighnāṃśāścaṣakāstathā ǁ
Lambanadyugataṃ tattu vijñeyaṃ ghaṭikādikam ǀ
Lambanadyugatasyātha svadinārdhavaśena yat ǁ
Nataṃ tenātha rahitā guṇitā viṃśatistataḥ ǀ
Lambanaṃ tadbhaved dvighnaviṣuvatkarṇabhājitam ǁ
Darśānte tadbhavet svarṇaṃ parapūrvakapālayoḥ ǀ
(RāMṛ, vii. 4-7 (a-b). Also see viii. 13 (c-d)-16 (a-b))

(2) Grahonalagnaṃ pañcaghnaṃ lambanadyugataṃ bhavet ǀ
Nataṃ tattithiviśleṣo natonatithirunnatam ǀ
Sārdhadvitayasaṃyuktamunnatārdhaṃ natāhatam ǀ
Viṣuvatkarṇasaṃbhaktaṃ lambanaṃ ghaṭikādikam ǁ
(GaĀ, iv. 14-15)

(3) Parvāntalagnaṃ kheṭonaṃ sāyakairnihataṃ kramāt ǀ
Tattanmānaphalairyuktaṃ bhāgādidviguṇaṃ ca yat ǁ
Lambanadyugataṃ tasmād bāṇacandrāntaraṃ natam ǀ
Natena hīnaṃ viṃśatyā nataṃ saṃguṇitaṃ tathā ǁ
Bhajettad dvyakṣakarṇena lambanaṃ ghaṭikādikam ǀ
(SiSā, vi. 1-3 (a-b)

(4) Lagnaṃ grahonaṃ pañcaghnaṃ lambanadyugataṃ yutau ǀ
Lambanadyugatāt pañcadaśabhirnatasādhanam ǁ
Kṛtirnatonāt tannighnād dvyakṣakarṇāptalambanam ǀ
Paścātprāgdyudalād darśe svarṇaṃ madhyāhnaparvaṇoḥ ǁ
(SiSaṃ, iv. 9-10)

7. LMā, vs 40: Rule for khārka or madhya-lagna.

This rule occurs in the Rājamṛgāṅka, the Gaṇakānanda, the Siddhānta-sāra, and the Siddhānta-saṅgraha as follows:

(1) Lambanadyugatāt śuddhe'mādinārdhe nataṃ matam ǁ
Pratykkapāle pūrve'mādinārdhād dyugate gate ǀ
Tithirmadhyagrahaṇikā saṃskṛtā lambanena yā ǁ
Tasyāḥ svamadhyāhnavaśāt yannataṃ ghaṭikādikam ǀ
Tasmācca pañcabhirlabdhaṃ yadrāśyādi phalaṃ bhavet ǁ
Phalena tena hīnāḍhyaḥ pūrvāparakapālayoḥ ǀ
Samalipto raviḥ kāryaḥ saḥ khārko bhavati sphuṭaḥ ǁ
(RāMṛ, vii. 7 (c-d)-10. Also see viii. 17-18 (a-b))

(2) Dyugataṃ lambanenonaṃ spaṣṭaṃ prāk pratyaganyathā ǀ
Taddinārdhāntaramnatā
Vyakṣāṃśakaḥ sāyanārkaḥ khārkaḥ pūrvāparāhṇayoḥ ǁ
(GaĀ, iv. 16-17 (a-b))

(3) Harijena yutaṃ hīnaṃ paścāt prāk parvaṇi sphuṭam ||
Tatkālanatabāṇāṃśabhāgena viyuto yutaḥ |
Sūryaḥ pūrvāparadiśo tadā khārko bhavedayam ||

(SiSā, vi. 3 (c-d)-4)

(4) Paścātprāg dyudalād darśe svarṇaṃ madhyāhnaparvaṇoḥ ||
Antarā natanāḍyastāḥ ṣaḍaghnā bhāgādayo ravau |
Dhanarṇaṃ pūrvavat khārkaścarāstasyaiva ṣaḍguṇāḥ ||

(SiSaṃ, iv. 10 (c-d)-11)

8. LMā, vs. 41: Rule for nati or parallax in latitude.
This rule occurs in the Rājamṛgāṅka, the Siddhānta-sāra, and the Siddhānta-saṃgraha. It is stated there as follows:

(1) Sāyanāṃśāttataḥ khārkāt prāgvat saṃsādhayeccaram |
Tat ṣaḍguṇaṃ palabhayā vibhajedyadavāpyate ||
Tena svarṇacaranyāyāt saṃskṛtā vyomasāyakāḥ |
Ūnā hatāḥ palabhayā dvighnāste'kṣadvibhājitāḥ ||
Kalādyaṃ yatphalaṃ labdhaṃ sā vijñeyā sphuṭā natiḥ |

(RāMṛ, vii. 11-13 (a-b))

(2) Ayanāṃśayutāt khārkāc caraṃ nītvā'ribhirhatam |
Viṣuvacchāyayā bhaktā natirdik khārkavadbhavet ||
Viṣuvacchāyayā hīnāḥ khabāṇāh prabhayā hatāḥ |
Sadā natirdakṣiṇā syād diktulye yutiranyathā ||
Antaraṃ taddvigunitaṃ vibhajed bāṇabāhubhiḥ |
Bhavedavanatirdik syādadhike vivare tu sā ||

(SiSā, vi. 5-7)

(3) Antarānnatanāḍyastāḥ ṣaḍghnā bhāgādayo ravau |
Dhanarṇaṃ pūrvavat khārkūścarastasyaiva ṣaḍguṇaḥ ||
Palabhāptaṃ dhanarnaṃ tu khārkānmeṣatulāditaḥ |
Palabhonābhrabāṇāśca palabhāghnāṃ sadā ṛṇam ||
Ṛṇasāmye dhanaṃ svarṇeṃ ṛṇaṃ dvighnaṃ śarāśvibhiḥ |
Labhā kalā yāmyanatirvyatyayāduttarā natiḥ ||

(SiSaṃ, iv. 11-14)

9. LMā, vss. 43-44: Rule for true semi-durations of eclipses.
This rule occurs in the Rājamṛgāṅka, the Gaṇakānanda, and the Karaṇāmṛta, and the Graha-gaṇita-bhāskara. It is stated there as follows:

(1) Tataśchādakamānārdhaṃ chādyamānārdhasaṃyutam |
Vidhāya sādhayedvargaṃ yuktavargaḥ sa ucyate ||
Yuktavargānmadhyaśaravargam samśodhya tatpadam |

Ṣaṣṭyā samgunya vibhajet spaṣṭayoścandrasūryayoḥ ||
Bhuktyantareṇa tanmadhyaṃ sthityardhaṃ ghaṭikādikam |
Vedābdhicandrairvibhajeccandrakṣepamanantaram ||
Labdhena ghaṭikādyena phalenonīkṛtaṃ tataḥ |
Sthityardhaṃ tadbhavet sparśaḥ sthityardhaṃ tatphalādhikam ||
Sthityardhaṃ maukṣikaṃ jñeyaṃ vipātendau samāṅghrige |
Tasmin viṣamapādasthe tadviparyayato bhavet ||
(RāMṛ, vi. 17-21. Also see, vii. 17-20)

(2) Kṣepavargonayoḥ kṛtyormānayogāntarārdhayoḥ ||
Pade ṣaṣṭihate tvekadiggatyorantareṇa ca |
Vakrarjugatiyutyā ca pravibhakte yathākramam ||
Madhyasthitivimardārdhe bhavetāṃ ghaṭikādike |
Candravikṣepakṛtendrāṃśayuktone sparśamokṣayoḥ ||
Sthityardhe ca vimardārdhe spaṣṭe syātāṃ same'nyathā |
(GaĀ, iv. 19 (c-d)-22 (a-b))

(3) Bimbayogāntaradalakṣepavargāntarāt pade |
Gatyantarāṃśakairbhakte dale sthitivimardhayoḥ ||
Sthityardhe candravikṣepakṛtendrāṃśayutonite |
Spaṣṭe spārśikamūnaṃ syādyugvikṣpe'nyathā mahat ||
Tadūnayutamāsāntadyugate lambane kṛte |
Sparśamokṣau raveḥ syātāṃ na lambanāvanatī vidhoḥ ||
(KA, iii, 15½-17½)

(4) Mānārdhayogasya kṛtirviśodhya
vikṣepavargaṃ pariśiṣṭamūlam ||
Ṣaṣṭyā hataṃ yadravicandrabhuktyo-
rviśleṣabhaktaṃ sthitikhaṇḍamāhuḥ |
Tadūnayuktau bhavataḥ praveśa-
mokṣau hi parvāntakamadhyakālau ||
Bimbāntarārdhasya kṛtiṃ viśodhya
vikṣepavargaṃ sthitikhaṇḍavatsyāt |
Vimardakhaṇḍau tata eva sādhyau
nimīlanonmīlanakālasaṃjñau ||
Vikṣepaliptākṛtaśakrabhāga-
yuktonitābhyāṃ sthitikhaṇḍakau staḥ |
Yugme pade vyatyayataśca siddhau
sthirīkṛtau sparśakamokṣakālau ||
(GGB, v. 3 (c-d)-6)

10. LMā, vs. 46: Rule for Akṣavalana.

This rule is found to occur in the Rājamṛgāṅka, the Grahaṇamaṇḍana of Parameśvara, the Gaṇakānanda and the Grahagaṇita-bhāskara:

(1) Sparśādikālasya natam svabhāghnam ravibhirbhajet |
Aṅgulātmakamākṣaṃ prāk saumyaṃ paścāttu dakṣiṇam ||
(RāMṛ, vi. 33. Also see vii. 39.)

(2) Natahatapalāṅgulebhyo dvādaśabhistvakṣavalanāḥ syuḥ ||
(GM, vs. 73 (c-d))

(3) Palabheṣṭanatābhyastā valanaṃ bhānubhājitā |
Uttaraṃ prāṅ ... paścāt valanaṃ radamaṇḍale ||
(GaĀ, iv. 30)

(4) Viṣuvatprabhayā samāhatā natanāḍī ravibhaktamakṣajam |
(GGB, vii. 5 (a-b))

11. LMā, vs. 47: Rule for Ayanavalana.
This rule occurs in Rājamṛgāṅka and the Gaṇakānanda:

(1) Samaujapadagagrāhyāt sāyanāṃśāt padaṃ hi tat |
Gataiṣyaṃ dviguṇaṃ taccāyanamaṅgulapūrvakam ||
(RāMṛ, vii. 40. Also see vi. 34-35 (a-b))

(2) Dvinighnā grāhyakheṭasya koṭirvalanamāyanam |
Anayoryogaviśleṣāt samabhinnadiśoḥ sphuṭam ||
(GaĀ, iv. 31)

APPENDIX 5

INDEX OF HALF-VERSES

(Numbers refer to verses)

APPENDIX 6

INDEX OF TECHNICAL TERMS
(Nūmbers refer to verses)

Aṃśa or Aṃśaka. Degree. (12, 14, 20, 51)
Akṣabhā. Same as Palabhā. (55)
Agastya. Canopus. (54)
Abhyāsa. Product; multiplication. (27)
Ayana. Solstice, winter or summer. (47)
Ayanacalana. Motion of the solstices; precession of the equinoxes. (5′)
Avantī. Ujjain. (20)
Asita. Dark portion of the Moon. (58)
Astārka. Longitude of the Sun when a planet or star sets heliacally. (53, 53′, 54)
Ucca. See Mandocca and Śīghrocca. (11, 18)
Uttaraviṣuvadādi. Vernal equinox. (5′)
Udagviṣuvadādi. Same as Uttaraviṣuvadādi. (22)
Udayārka. Longitude of the Sun when a planet or star rises heliacally. (54)
Ojapada. Odd quadrant. (12)
Kalā. Minute of arc. (5, 7, 12, 34)
Kendra. Anomaly. (11)
Koṭi. See vs. 12. (11, 12, 13, 14, 16, 18)
Kṣepa. Celestial latitude. (51, 52)
Khārka. Meridian-ecliptic point. (40)
Guṇa. Multiplier. (18, 22, 27, 28, 29)
Guṇaka. Multiplier. (30)
Grahaphala. Correction for a planet. (14)
Cara. Twice the ascensional difference. (22, 23, 25, 26, 41, 51, 55)
Candrapāta. The ascending node of the Moon's orbit. (10)
Chādaka. Eclipser. (42)
Chāyāgraha. A hypothetical planet which is supposed to be diametrically opposite to the Sun. (34)
Chinna. Divided. (4)
Cheda. Divisor. (13-17, 28, 33, 34, 35, 37, 58′)
Tārāgraha. The planets Mars, Mercury, Jupiter, Venus and Saturn are called Tārāgraha or star-planets in Hindu astronomy. (16)
Tithyatdha. Karaṇa, one of the five elements of the Hindu Pañcāṅga. (21, 58′)
Doḥ. Same as Bhuja. (12, 16, 18)
Dṛkkarma. Visibility correction. (57)
Dyugaṇa. Ahargaṇa minus 357 times the number of years elapsed since the epoch. (4, 5, 6, 7)
Dhruva, or Dhruvaka. Initial or epochal constants. (2, 4′)
Dhruvādi. The time for which the initial constants are computed. (3, 8)
Dhruvavāsara. The day for which the initial constants are computed (4)
Nata. Hour angle. (27, 39, 40)

Natanāḍikā. Hour angle in terms of nāḍīs. Nāḍī or nāḍikā is a unit of time equal to 24 minutes. (25, 30)
Nati. Parallax in latitude. (41, 42)
Palabhā. Equinoctial midday shadow. (26, 41, 46, 56)
Pāta. Ascending node. (4′, 36)
Prakāśa. Name of a town in northern India. (1)
Bāhu. Same as Bhuja. (12)
Bha. Nakṣatra, one of the five elements of the Pañcāṅga. (21)
Bhagaṇa. Revolution (lit. collection of the twelve zodiacal signs) (3′)
Bhā. Shadow. (26)
Bhāga. Degree.
Bhuja. See vs. 12. (11, 14, 22, 36)
Bheda. Occultation of one planet by another. (38)
Bhodaya. Time taken by a sign in rising above the eastern horizon. (53)
Maddhacchāyā. Midday shadow. (28)
Madhyasphuṭa. True mean planet, i.e. mean planet as corrected for the equation of the centre. (36)
Mandocca. Apogee. (2′)
Māsāntadyugata. Day elapsed since sunrise at the end of a lunar month. (45)
Mānaikyārdha. Half the sum of the eclipsed and eclipsing bodies. (43)
Yoga. (1) One of the five elements of the Pañcāṅga. (21)
(2) Conjunction in longitude. (31)
Rāśi. Zodical sign. (12)
Rāhu. Moon's ascending node. (4′)
Lagna. Rising point of the ecliptic, the ascendant. (24, 45, 52)
Lambana. Parallax in longitude. (39, 40, 45)
Liptā (or Liptikā). Minute of arc. (5′, 20)
Valana. Deflection. Deflection due to latitude is called akṣavalana and that due to declination is called ayanavalana. (46, 47, 48, 53′, 58)
Viksepa: Celestial latitude. (37, 38, 42, 44, 49, 50, 53′, 55, 58)
Vilagna. Sama as Lagna. (57)
Vilomaga. A heavenly body that moves in the opposite or negative direction, i.e., from east to west. (10)
Viṣuvacchāyā. Equinoctial midday shadow. (22, 54)
Vaidhṛta. A heavenly phenomenon that occurs when the sum of the tropical longitudes of the Sun and Moon equals 360° and the declinations of the Sun and Moon are numerically equal. (56)
Vyāsa. (15, 17)
Vyatīpāta. A heavenly phenomenon that occurs when the sum of the tropical longtiudes of the Sun and Moon equals 180° and the declination of the Sun and Moon are numerically equal. (56)
Śīghraphala. Correction due to Śīghrocca. (17)
Śīghrocca. Planet or Sun, whichever is faster. (16)

Samapada. Even quadrant. (12)
Saṅkrānti. The time when the Sun crosses from the sign into the next. (2, 3)
Sita. The illuminated or bright portion of the Moon. (58)
Sthitidala. Semi-duration of an eclipse. (43)
Saurivāra. Saturday. (1′)
Hara. Divisor. (17, 33)

LAGHUMĀNASA

ENGLISH TRANSLATION
AND
COMMENTARY

Chapter I

DHRUVAKAS OR CONSTANT PARAMETERS

INTRODUCTION

1. I, (Mañjulācārya), famous as the Sun in Prakāśa (pattana), born in the Bharadvāja Gotra, best among the Brāhmaṇas, set forth another work, entitled Laghumānasa, which is small and contains brief and unprecedented methods of planetary computation. (1)

Prakāśa-pattana, according to the commentator Yallaya, was a town in northern India. Mallikārjuna Sūri has mentioned it in his commentary on Lalla's Śiṣya-dhī-vṛddhida and has made computations for this place.[1]

From Mallikārjuna Sūri's commentary we learn that the town of Prakāśapattana was situated at a distance of 80 yojanas (or 9° 40′) to the east of the Hindu prime meridian and the length of the equinoctial midday shadow there was 5¾ aṅgulas (digits). Calculation from this data shows that this town must have been located in latitude 25°36′N. and longitude 85°6′E.,[2] i.e., somewhere near modern Patna (lat. 25°22′N.. long. 85°8′E.).

"Prakāśādityavat khyātaḥ" has been translated above as "famous as the Sun in Prakāśa (pattana)". It may also be translated as "well known as light (prakāśa) and Sun (āditya)", meaning thereby that the author of the Laghumānasa was called by a name which meant "sun" (and probably also "light"). The commentator Yallaya says:

> "Prakāśa (or light) is well known. That and also Āditya (or Sun). Known as they are. I am known in the same way as those people in the world who bear the name Āditya. I am as famous as the Sun that destroys the darkness pervading the interior of the universe (brahmāṇḍa). The elderly people give an alternative meaning also. There is a town called Prakāśa in the northern part of the country. People there, in their own regional dialect, call the Sun by the name Mañjula. Known as that, i.e., as Mañjulācārya."

> "He is called "best among the Brāhmaṇas" ", continues Yallaya "because (besides being a Brāhmaṇa), he was an Ācārya. The elderly people indeed say: Whereas Āryabhaṭa knows Grahagaṇita ("Mathematics of Planets") or Planetary

[1] See com. on ŚiDVṛ, xii. 11-12.

[2] We have taken the Earth's equatorial circumference as equal to 3300 yojanas as given in the Śiṣya-dhī-vṛddhida and the Hindu prime meridian as the meridian of Ujjain (long. 75° 26′ E.). Unfortunately, the position of the Hindu prime meridian is not well-defined. Although all Hindu authorities take it as passing through Ujjain, they do not seem to take it as identical with the meridian of Ujjain as we now know it.

Astronomy, Dāmodara knows Gola ("the Celestial Sphere") or Spherical Astronomy, and Jiṣṇusuta (Brahmagupta) knows Yantra (Instruments) or Practical Astronomy, Mañjulācārya knows all of them."

Summing up the contents of the verse, Yallaya writes:

"The inhabitants of Śrīmat Prakāśa-pattana, in their regional dialect, call the Sun as Mañjula. A brāhmaṇa bearing the name Mañjula, who earlier wrote a large book on astronomy in the form of dialogue with his pupil, later wrote a calendrical work and called it Laghu-mānasa, i.e., Small Mānasa, to distinguish it from the larger work. Just as the Sun is well known in the world, so is he (Mañjulācārya) well renowned."

The commentator Praśastidhara, however, interprets prakāśādityavat khyātaḥ in a different way. He says:

"Just as God Sun of the town of Prakāśa-pattana is renowned in all quarters, so is Ācārya Mañjula of the same town renowned in the same way."

So also interprets the commentator Sūryadeva Yajvā:

"In some region towards the north of the country there is a town known as Prakāśa. The idol of God Sun is installed there. Present in his idol, He is worshipped by all people of that region. Just as He is famous in all quarters, so is (Mañjula) renowned like Āditya (i.e., Sun). By saying this he means to say, for the instruction of his pupils, that he is providing an auspicious introduction in the form of prayer to his favourite deity (the Sun) for the sake of successful completion of the calendrical work which is at the start. Also that Muñjālācārya (Mañjulācārya), renowned in the region, proficient in all mathematical sciences, best among the Brāhmaṇas, born in Bharadvāja Gotra lives in that very town."

Commenting on the adjective "anyat" (another) applied to Laghumānasa, Sūryadeva Yajvā says:

"(Ācārya Muñjāla) having studied the Mahā-mānasa and many other works on astronomy and having summarized in 60 verses in anuṣṭubh metre the astronomy stated there, wrote the calendrical work entitled Laghumānasa and got it copied neatly by one of his pupils to show it to the king of the region. That wicked pupil taking those verses to the king told him that he himself wrote the calendrical work entitled Laghumānasa. The wise king advised him to show it to his teacher. Thereafter, when Muñjāla happened to visit the king, the king asked him whether his pupil had written the calendrical work entitled Laghumānasa. At this Muñjāla laughed. The king asked him the reason of his laughter. Muñjāla replied: "Your Majesty being the king, all people are competent to do all things: this is why I laughed." The king then said: "Tell me how to know the fact." "Let this calendrical work remain in your custody and let both of us under your protection be asked to write another calendrical work this very day," said Muñjāla. Both of them were then put under guard by the king (and asked to write another calendrical work). Muñjāla then in a short time remembering the earlier multipliers and divisors etc. and summarizing them in an unusual way composed another Laghumānasa and showed it to the king. His pupil, on the other hand, could not do anything. Thereupon the king getting angry with that pupil for the wrong done by him to his teacher banished him from his kingdom. To Muñjāla he gratified with presents and honours etc. and destroying the earlier calendrical work made this second calendrical work known to the world. This is why it has been qualified by the adjective "anyat"."

According to the commentators Parameśvara and Yallaya, however, the word "anyat" means "different from Bṛhanmānasa (the larger work of Mañjula)".

Thus, according to the commentators, the author of the present work bore the name Mañjula which meant "Sun" in the regional language which was in vogue at Prakāśapattana where he lived. This Prakāśapattana had also a temple of God Sun which was famous in the region.

COMPUTATION OF PLANETS: PRELIMINARY INSTRUCTION

2. Knowing the week-day, the Saṅkrānti tithi, the positions of the Sun, Moon, the apogees (Uccas) of the planets for the beginning of Caitra (of the epochal year) together with the epochal Saka year (known as Dhruva) as well as the other elements (such as the positions 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). (2)

One should first choose some year of the Śaka era (preferably the current Śaka year) as the epochal year (Dhruva), and then calculate the positions of the Sun, Moon and the apogees of the planets for the beginning of Caitra of that year as also the positions of the planets, the ascending nodes of the planets (including the Moon also), as well as the precession of the equinoxes for the beginning of the mean solar year occurring after the beginning of Caitra. One should also find the week-day falling on the first day of Caitra as well as the Saṅkrānti tithi, i.e., the tithi of the Meṣa-saṅkrānti day (or the number of tithis lying between Caitrādi and Meṣa-saṅkrānti). Meṣa-saṅkrānti is the time of Sun's entrance into the sign Aries. Using this data (constituting the so called pūrva-dhruvas, initial or epochal constants), one can calculate the positions of the planets for any other time by applying the rules stated below. These positions, it is presumed, will be correct if calculated within one hundred years from the epoch chosen.

For the convenience of the astronomers of his time, Mañjula has given the positions of the planets etc. constituting the initial constants corresponding to the Śaka year 854 treating it as the epochal year. These are as follows:

EPOCHAL POSITIONS

(Dhruvas or Purva-dhruvas)

Positions for Saturday noon, Caitrādi, Śaka 854, A.D 932

1′-2′. On Saturday[1] noon, the beginning of Caitra, Śaka year 854, (the positions of the Sun, Moon, and the apogees of the planets are as follows):[2]

Sun	$11^s16°12'$
Moon	$11^s18°22'$
Apogee of:	
Sun	78° or $2^s18°$
Moon	7⅓° or 0^s 7° 20′
Mars	127° or 4^s 7°
Apogee of:	
Mercury	220° or 7^S 10°
Jupiter	172° or 5^s 22°
Venus	80° or 2^s 20°
Saturn	247° or 8^s 7°

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

3′-5′. And at the completion of the Sun's revolution (in Śaka 854) (the positions of the planets and their ascending nodes, etc., are as follows):

Mars	2^s 26° 00′
Śīghrocca of Mercury	4^s 26° 42′
Jupiter	0^s 8° 9′
Śīghrocca of Venus	10^s 3° 33′
Saturn	9^s 28° 49′
Saṅkrānti tithi (i.e. tithi of Meṣa-saṅkrānti day)	14
Ascending node of:	
Moon	8^s 9° 56′
Mars	40°

[1]According to Mss. F and G, it is Sunday (Sauravāra or Ravivāsara).

[2]According to Āryabhata I's constants, the Kaliyugādi Ahargaṇa for this epoch, as calculated by Sūryadeva Yajvā, is 1473074¼.

Mercury	20°
Jupiter	80°
Venus	60°
Saturn	100°
Ayana-calana or precession of the equinoxes	6° 50′
Rate of ayana-calana	1′ per year.

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

The commentator Sūryadeva Yajvā has examined the above data and has given the full rationale of it. He has shown that the above-mentioned positions of the planets have been calculated from the following revolutions taken from the Āryabhaṭīya of Āryabhaṭa I, the Brāhma-sphuṭa-siddhānta of Brahmagupta and the Sūrya-siddhānta (which were the standard works on astronomy in the time of Mañjula):

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

Sūryadeva Yajvā has shown that the Bīja corrections have also been applied. In the case of Moon, Śīghrocca of Mercury, and Jupiter, where the mean positions have been derived from the revolutions stated in the Āryabhaṭīya, the traditional Bījas of the Āryabhaṭa school have been used. These are:[1]

Moon	− 25/235	min. per year since Śaka 444
Ś of Mercury	+ 430/235	,, ,, ,,
Jupiter	− 50/235	,, ,, ,,

[1]Candre bāṇkarā (25) bījāścandrocce manubhūmayaḥ (114)
Kuje śūnyaśarā (50) jñeyāḥ khāgnivedā (430) budhasya tu
Guroḥ khapañca (50) vijñeyāḥ śukre khāṣṭaniśākarāḥ (180)
Śaneḥ śaśikarāḥ (21) proktā rāhoḥ ṣaṇṇavatiḥ (96) smṛtaḥ
Bhavabhā (444) nūnite śāke bījaghne śabaro (235) ddhṛte
Phalaṃ liptā viliptāśca jñārārkīṇāṃ dhanaṃ bhavet
Rāhucandroccajīvānāmṛṇaṃ kāryaṃ bhṛgorapi

In the case of Śīghrocca of Mercury, however, Śaka 444 has been replaced by Śaka 420, so that in computing the Bīja correction in this case 420 has been subtracted from the current Śaka.

In the case of Mars, where too the mean position has been derived from the revolutions stated in the Āryabhaṭīya use has been made of the bīja corrections prescribed by Bhaṭṭotpala, viz. 36′ + [(¼)′ per year since Śaka 587].[1]

The Sūrya-siddhānta does not prescribe any Bīja correction. So in the case of the Śīghrocca of Venus where the mean longitude has been derived from the revolutions stated in the Sūrya-siddhānta, no Bīja correction has been applied.

In the case of Saturn where the mean position has been calculated from the revolutions stated in the Brāhma-sphuṭa-siddhānta, no Bīja correction has been used.

The commentator Yallaya, however, is of the opinion that in the case of all the planets excepting the Śīghrocca of Venus and Saturn, the Bīja correction used is not the traditional Bīja of the Āryabhaṭa school but another Bīja of the same school, viz.[2]

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

[1] Agavaṣuśara (587) śakakālāntaraḥ smṛtaḥ karaṇavatsarasaṁgrahaḥ
Tasmāddhṛtyaṁśa (1/18) kalāḥ saṣaṭ (6) kalāśśītagoḥ śodhyāḥ
Ardhaṁ (1/2) saptatyadhikaṃ (70) liptādyaṃ śodhayecchaśāṅkoccāt
Pañcāṃśa (1/5) kalārahitaṃ pañca (5) kalāsaṃyutaṃ kendram
Pādaḥ (1/4) saṣaṭkṛti(36)kalaḥ kṣepyaḥ kṣitinandanasya liptāsu
Triṃśāṃśāi(1/30)kādaśa (11) yugdhanaṃ labhejjñacalabhāgeṣu
Ṣaḍbhāga (1/6) kalārahitaḥ pañcāśa(50)lliptikādhikaśca guruḥ
Pādo(1/4)nakalārahitaḥ sitaścatustriṃśat (34) kalonaḥ
Vasvaṃśa (1/8) kalādyadhiko'ṣṭādhikadaśa (18) liptikādhikaśca śaniḥ
Aṃśaḥ (1) saṣaṭkṛtikalaḥ śodhyaḥ pātasya pūrvasya
(Quoted in Sūryadeva Yajvā's commentary. Also see KK (Bina Chatterjee's ed., vol. I, pp. 162-163.)

[2] Yugayātavarṣavṛndāt khatarkavargeṇa (3600) bhājitāccheṣam
Kṛtvā haradalato'lpaṃ guṇakairguṇayed haret khatattvaiśca (250)
Tattvānya(25)ṣṭasamudrāḥ (48) kharāmavedāḥ (430) muniśrutayaḥ (47)
Śaśikujabudhajīvānāṃ śaśāṅkatuṅgasya vedeśāḥ (114)
Rasanandāḥ (96) pātasya śaśāṅkatattuṅgapāteṣu
Surasacive ca viśodhyaṃ kalādyamaṅgārake budhe yojyam
Cf. Lalla's Bīja, Śāke nakhābdhirahite etc.

Apogees of the planets

As regards the positions of the apogees of the planets, the Sun's apogee is the same as stated in the Āryabhaṭīya[1], the Moon's apogee has been calculated by taking the yuga revolutions stated in the Āryabhaṭīya (viz. 488219) and applying the Bīja correction prescribed by Bhaṭṭotpala, viz.

– (70′ + ½ min. per year since Śaka 587).

Mars' apogee is the same as stated in the Uttara-Khaṇḍakhādyaka;[2] those of Mercury and Venus, the same as stated in the Pūrva-Khaṇḍakhādyaka[3]. The apogee of Jupiter has been obtained according to Brahmagupta by taking 855 as the number of revolutions in a Kalpa ("a period of 43,20,000,000 years"). The apogee of Saturn is Mañjula's own.

Ascending nodes of the planets

As regards the ascending nodes of the planets Mars etc., the positions adopted by Mañjula are the same as stated by Āryabhaṭa I in his Āryabhaṭīya[4] and by Brahmagupta in his Khaṇḍakhādyaka[5]. The Moon's ascending node has been calculated by taking the yuga revolutions stated in the Āryabhaṭīya (viz. 232226) and applying the traditional Bīja correction of the Āryabhaṭa school, viz. – 96/235 min. per year since Śaka 444.

Mean position

The rules to be used for finding the mean positions are those prescribed in the respective works. It may, however, be mentioned that the number of years elapsed at the commencement of Śaka era since the beginning of Kalpa, according to Brahmagupta and the Sūrya-siddhānta, is 1,97,29,47,179; and the number of years elapsed at the commencement of the Śaka era since creation, according to the Sūrya-siddhānta, is 1,97,29,47,179 minus 1,70,64,000, i.e., 1,95,58,83,179.

The following constants have also been used in the Laghu-mānasa. These are the same as stated in the Āryabhaṭīya.

Solar months in a yuga	5,18,40,000
Lunar days in a yuga	1,60,30,00,080
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

[1] i. 9 (c-d).
[2] See: KK (Bina Chatterjee's ed.), Vol. II, xi. 1.
[3] See: KK (Bina Chatterjee's ed.), Vol. II, ii. 6 (a-b).
[4] i. 9 (a-b).
[5] See: KK (Bina Chatterjee's ed.), Vol. II, viii. 1 (a-b).

The initial constants stated by Mañjula were meant to be used for 100 years. After 100 years they had to be computed afresh. The commentators Praśastidhara, Sūryadeva Yajvā, Parameśvara, Makaranda, and Yallaya have calculated the initial constants for Śaka 880, Śaka 1170, Śaka 1331, Śaka 1400, and Śaka 1404 respectively, each for Caitrādi noon. Some anonymous astronomer, probably Mallikārjuna Sūri, computed the inital constants for Caitrādi noon, Śaka 1100. These are found to be used by certain astronomers of Āndhra Pradeśa in their computations of the eclipses based on the methods taught in the Laghumānasa.

Computation of the Śaṅkrānti tithi

In order to obtain the Śaṅkrānti-tithi (i.e., the number of tithis lying between Caitrādi and the Meṣa-saṅkrānti), the commentator Praśastidhara gives two rules, one approximate and the other accurate:

> Approximate rule. The degrees to be traversed by the Sun from the Caitrādi up to the Meṣa-saṅkrānti gives the Saṅkrānti-tithi.

As for example, the Sun's longitude for the Caitrādi of the Śaka year 854 = $11^s\ 16°\ 12'$, and the Sun's longitude at the Meṣa-saṅkrānti = 12^s. Their difference = $13°\ 48'$. Therefore, the Saṅkrānti-tithi = 14, as stated by Mañjula.

Accurate Rule. Find the difference (between the positions of the Sun and Moon at noon occurring before or after Caitradi), (in terms of minutes). (Multiply that by the Sun's daily motion and divide by the motion-difference of the Sun and Moon). Add it to or subtract it from the Sun's longitude, according as the Sun's longitude is greater or less than the Moon's longitude. Subtract that from a circle (or 360°): then multiply that by 100 and divide by 97: the quotient gives the Saṅkrānti-tithi.

Its rationale. Suppose that the longitudes of the Sun and Moon at noon occurring before the beginning of Caitra are S and M respectively, S being greater than M. Also suppose that $S - M = D$.

In the beginning of Caitra $D = 0$, so that the motion of the Sun from that noon up to the beginning of Caitra

$$= \frac{\text{Sun's daily motion} \times D}{\text{motion-difference of Sun and Moon}}$$

Therefore, Sun's longitude in the beginning of Caitra

$$= S + \frac{\text{Sun's daily motion} \times D}{\text{motion-difference of Sun and Moon}}$$

$= S'$ degrees, say.

Now the Sun's longitude at Meṣa-saṅkrānti = 360°. Therefore

$$\text{Saṅkrānti-tithi} = \frac{(360^\circ - S') \times (\text{tithis in a yuga})}{\text{degrees of Sun's motion in a yuga}}$$

$$= \frac{(360^\circ - S') \times (\text{tithis in a yuga})}{\text{solar days in a yuga}}$$

$$= \frac{(360^\circ - S') \times 1603000080}{1555200000}$$

$$= \frac{(360^\circ - S') \times 100}{97}$$

Hence the rule.

The commentator Sūryadeva Yajvā finds the Saṅkrānti-tithi for the Śaka year 854 by converting into tithis the adhimāsa-śeṣa for the end of the Śaka year 854. This is also correct, because the adhimāsaśeṣa, converted into tithis, too gives the number of tithis lying between Caitrādi and Meṣa-saṅkrānti.

Ayana-calana or precession of the equinoxes.

To calculate the amount of precession of the equinoxes (ayanacalana), Mañjula has used the formula:[1]

ayanacalana = (Śaka year — 444) minutes.

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

ayanacalana = (854 – 444) mins. = 410′ or 6° 50′.

And the rate of precession is 1′ per year.

In his Bṛhanmānasa, Mañjula is alleged to have given 199669 as the revolution-number of the vernal equinoctial point in a period of 4320000000 years. This yields 59″.9 as the annual rate of precession of the equinoxes. If precession of the equinoxes be assumed to be non-existent in Śaka 444, then at this rate its value in Śaka 854 will amount to

[1] Kṛtayugavedavihīnācchakakālādyadavaśisyate śeṣam
Ayanacalanaṃ grahāṇāṃ krāntyarthaṃ dīyate tajjñaiḥ

(From Nakṣatrapatrikā)

$$\frac{199669 \times (854-444)}{200000} \text{ mins.}$$

$$= 409' \ 19'' \text{ or } 6° \ 49' \ 19''$$

which is roughly equal to 6° 50′, the value stated by Mañjula in the present work.

It is noteworthy that verses 1′ to 5′ giving the epochal positions, though composed by Mañjula himself, have been put in the āryā metre and not in the anuṣṭubh metre in which the 60 verses of the Laghumānasa have been composed. According to Sūryadeva Yajvā, this has been done for two reasons:

(1) To tell the reader that the epochal positions stated in those verses will not serve for ever but for 100 years only, and after every 100 years thereafter they will have to be replaced by new verses giving new epochal positions.

(2) To suggest that the new verses giving new epochal positions should also be composed in a metre different from the anuṣṭubh so that they may not be mixed up with the 60 verses of the Laghumānasa.

We actually find that the new verses giving new epochal positions as composed by Praśastidhara, Sūryadeva Yajyā, Mallikārjuna Sūri, and Yallaya are all in the āryā metre.

Chapter II

MEAN MOTION

DYUGAṆA

1-2. Multiply the number of years elapsed since the epoch (Dhruvādi or Dhruvābdādi) by 10; then add to it one-eighth of itself;[1] and then add the Saṅkrānti tithi. Put down the result in two places, one below the other. In the lower place, deduct 1/60 of itself[2] 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 the Caitrādi); from that subtract 3 times the number of years elapsed (since the epoch) and also the number of seasons elapsed (since the Caitrādi 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. (3-4)

That is:

$$\text{Dyugaṇa} = 10Y + 10Y/8 + S_t - R + C_t - 3Y - s.$$

where R is given by

$$(10Y + 10Y/8 + S_t)(1 - 1/60) = 30Q + R,$$

and Y = years elapsed since the epoch
S_t = Saṅkrānti tithi
C_t = Caitrādi tithis
s = seasons elapsed since Caitrādi.

The rationale of this rule is as follows:

Let A be the Caitrādi of the Dhruvābda, B the Caitrādi occurring Y lunar years thereafter, C the Caitrādi of the current year, and T the beginning of the tithi for which the Dyugaṇa is to be calculated.

A————S————B————C————Ś————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).

[1] "One-eighth of itself" should be taken in whole numbers, the fractional part should be rejected.
[2] "1/60 of itself" should be taken in whole numbers, the fractional part should be rejected.

There are approximately 354 civil days in a lunar or synodic year and 365¼ civil days in a solar year,[1] so that

no. of civil days from A to B = 354Y
no. of civil days from S to Ś = 365¼Y.

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 S + civil days from S to Ś − civil days from A to B
= Saṅkrānti tithi + 365¼Y − 354Y
= Saṅkrānti tithi + 11¼Y
= Saṅkrānti tithi + 10Y + 11/8 Y = X, say,

where Saṅkrānti 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 years	= 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

$$= \frac{1593336 \times 100}{4320000} \text{ months} = 36 \text{ months } 26 \text{ days.}$$

[1]The Mysorean commentator (see Ms. F) takes the no. of civil days in a solar year = 365·2586 (the same as taken by Āryabhaṭa), so he takes 365·2586 = 10 + 10/8 + 10/8 × 144, and makes the corresponding modification in the rule.

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

$$\text{no. of civil days from B to C} = X - R.$$

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

$$\text{no. of civil days from C to T} = C_t - s.$$

(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.)

Therefore,

$$\text{no. of civil days from B to T} = X - R + C_t - s.$$

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

Subtracting 357Y from it, we get

$$\begin{aligned} \text{Dyugaṇa} &= X - R + C_t - s - 357Y \\ &= X - R + C_t - s - 3Y \pmod 7 \end{aligned}$$

Thus we see that

$$\text{Dyugaṇa} = \text{Ahargaṇa} - 357Y.$$

Since 357Y 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.

Majumdar's Rationale: N.K. Majumdar has given the following rationale:

"The calculations are based on a lunar year of 354 days and a solar sidereal year of 365¼ days.

In 354 days there are therefore 12 × 30 or 360 tithis. In each solar sidereal year of 365¼ days, there are (365¼ − 354) or 11¼ (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 Saṅkrānti Tithis at Varśādi of Epoch added to the total number of tithis calculated above gives the total number of additional tithis from Caitrādi 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 Adhiśaṣa or lunar tithis from Caitrādi to Varṣādi of current year.

Deducting this number of Adhiśeṣas from the additional lunar tithis found before, the number of additional days (i.e., omitting 354 days for each year) from Caitrādi of Epoch to Caitrādi (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.

The number of tithis elapsed from the Caitrādi 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 the Ahargaṇa. Ahargaṇa is thus equal to Dyugaṇa plus 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 the commentator Sūryadeva Yajyā, it means "the day which occurs next to the day for which the epochal constants are computed"[1] i.e. Sunday. It means that, according to him, the epochal day of the Laghumānasa is Sunday, not Saturday, although he does not expressly state it. Mss. F and G clearly say that it was Sunday on the first tithi of Caitra in Śaka 854. According to Śaṅkara Bālakṛṣṇa Dīkṣita too, the first tithi of Caitra in Śaka 854 occurred on Sunday.[2]

[1] Dhruvavāsarāt yasmin vāre dhruvako nibaddhaḥ tadanantaravārāt prabhṛti tasmin dyugaṇe vārā gaṇanīyā ityarthaḥ.

[2] See Bhāratīya Jyotiṣa-śāstra cā Itihāsa (Marāṭhī), Second Edition, 1931, p. 314, line 5.

The next six verses state how to find the mean longitudes of the Sun, Moon, and the planets. In verses 5, 6 and 7 are stated formulae giving the mean motions of the Sun, Moon and Moon's apogee since the beginning of Caitra in Śaka 854 (which is taken as the epoch). To get the mean longitude in the case of these three, one has simply to add to the resulting mean motion the corresponding mean position at the epoch (stated in vss. 1′ and 2′).

MEAN SUN

3. 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 Dyugana 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.) (5)

In other words:

Sun's mean motion since the epoch

$$= \left[D - \frac{D + 10Y}{70} - 8Y \right] \text{degrees} + (Y/8) \text{ mins.},$$

where D ≡ Dyugaṇa, and Y ≡ years elapsed since the epoch.

The following is the rationale of this rule:

According to Āryabhaṭa I,

$$\text{Sun's mean daily motion} = \frac{4320000 \times 360}{1577917500} \text{ degrees}$$

$$= \frac{576 \times 360}{210389} \text{ degrees}$$

$$= (1 - 1/70) \text{ degrees} - 2/5 \text{ secs. approx.}$$

(See ŚiDVṛ, i. 33)

Mañjula neglects 2/5 secs. and takes

Sun's mean daily motion = (1 − 1/70) degrees approx. (1)

Also according to Āryabhaṭa I,

Sun's mean motion for 357 days $= (352 - 1/7)$ degrees $+ (1/5)$ mins.

$$= -8\frac{1}{7} \text{ degrees} + (1/5) \text{ mins.}$$

Mañjula takes (1/8) mins. in place of (1/5) mins., so that according to him

$$\text{Sun's mean motion for 357 days} = -8\frac{1}{7} \text{ degrees} + (1/8) \text{ min.} \tag{2}$$

Let A denote the Ahargaṇa, D the Dyugaṇa, and Y the number of years elapsed since the epoch. Then

$$A = D + 357Y,$$

so that, using (1) and (2), we have, according to Mañjula,

Sun's mean motion corresponding to the Ahargaṇa A

$$= (1 - 1/70)\, D \text{ degrees} - 8\frac{1}{7}\, Y \text{ degrees} + (1/8)\, Y \text{ mins.}$$

$$= \left[D - \frac{D + 10Y}{70} - 8Y \right] \text{degrees} + (1/8)\, Y \text{ mins.}$$

This increased by the Sun's position at the epoch gives the Sun's mean longitude.

Note. If $8Y > D - \frac{D + 10Y}{70}$ then, according to Ms. F, one should subtract $8Y$ from $180 + D - (D + 10Y)/70$. This is obviously true.

MEAN MOON

4. Set down 13 times the Dyugaṇa 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 the mean motion of) the Moon (since the epoch), in terms of degrees. (6)

In other words:

$$\text{Moon's mean motion since the epoch} = 13D + \frac{13D - (D + 3Y)}{68} + 24Y \text{ degrees},$$

where D stands for Dyugaṇa and Y for the number of years elapsed since the epoch.

The following is the rationale of this rule:

According to Āryabhaṭa I,

$$\text{Moon's mean daily motion} = \frac{57753336 \times 360}{1577917500} \text{degrees}$$

$$= \left(13 + \frac{13-1}{68} \right) \text{degrees} - (1/150) \text{ secs.}$$

Mañjula neglects − (1/150) secs. and takes

$$\text{Moon's mean daily motion} = \left(13 + \frac{13-1}{68} \right) \text{degrees.}^{1} \qquad (1)$$

Again, according to Āryabhaṭa I,

$$\text{Moon's mean motion for 357 days} = \frac{57753336 \times 357}{1577917500} \text{revs.}$$

$$= 13 \text{ revs.} + (24 - 3/72) \text{ degrees}$$

$$= (24 - 3/72) \text{ degrees, neglecting revolutions.}$$

Mañjula replaces 3/72 by 3/68, and takes

Moon's mean motion for 357 days
= (24 − 3/68) degrees, neglecting revolutions. (2)

Using (1) and (2), Mañjula takes

Moon's mean motion since the epoch

$$= \left[13D + \frac{13D - (D + 3Y)}{68} + 24Y \right] \text{degrees.}$$

This increased by the Moon's position at the epoch gives the Moon's mean longitude.

MOON'S APOGEE

5. Subtract 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. Subtract minutes equal to (1 + 1/8) times the years elapsed. (Then is obtained the mean motion of the Moon's apogee since the epoch). (7)

[1] This result is the same as stated in the following verse which Sūryadeva Yajvā ascribes to Lalla:
Divāgaṇādviśvahatāt pṛthaksthitād divāgaṇonādvasuṣaṭkabhājitāt ।
Phalānvitādvā himaguprasiddhaye kṣipenmṛgāṅkadhruvake'ṃśakādikam ॥

In other words:

Mean motion of Moon's apogee since the epoch

$$= \left[\frac{D - 2Y}{9} + 40Y\right] \text{degrees} - (1 + 1/8) \text{ mins.},$$

where D denotes Dyugaṇa and Y the number of years elapsed since the epoch.

The rationale of this rule is as follows:

According to Āryabhaṭa I,

$$\text{Mean daily motion of Moon's apogee} = \frac{488219 \times 360}{1577917500} \text{ degrees}$$
$$= 1/9 \text{ degrees} + 1/61 \text{ min.}$$ [1]

Mañjula neglects 1/61 min. and takes

Mean daily motion of Moon's apogee = 1/9 degrees. (1)

Again, according to Āryabhaṭa I,

Mean motion of Moon's apogee for 357 days

$$= \frac{488219 \times 360 \times 357}{1577917500} \text{degrees}$$
$$= (40 - 2/9) \text{ degrees} - 6/8 \text{ min.}$$
$$= (40 - 2/9) \text{ degrees} - 9/8 \text{ min.} + 3/8 \text{ min.}$$

Manjula 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

$$= D/9 \text{ degrees} + (40 - 2/9)\, Y \text{ degrees} - (9/8)\, Y \text{ mins.}$$
$$= \left(\frac{D - 2Y}{9} + 40Y\right) \text{degrees} - (1 + 1/8)\, Y \text{ mins.}$$

This increased by the position of the Moon's apogee at the epoch gives the mean longitude of the Moon's apogee.

[1] See ŚiDVṛ, i, 38(c-d).

In the case of Mars, Śīghrocca of Mercury, Jupiter, Śīghrocca of Venus, Saturn, and Moon's ascending node, whose mean longitudes have been stated (in vs. 3′) 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 since the 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 (obtained in vs. 5) in terms of signs etc.

MEAN MARS

6 (a-b). 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 the place of revolutions) divided by 2, plus 16 times the Dhruvādyarka divided by 505, gives the mean motion of Mars since the epoch.

In other words:

$$\text{Mean motion of Mars since the epoch} = S/2 + 16S/505,$$

where S is the Dhruvādyarka.

This is true, because (according to Āryabhaṭa I),

$$\frac{\text{mean motion of Mars since the epoch}}{\text{mean motion of Sun since the epoch}} = \frac{2296824}{4320000}$$
$$= (1/2) + (16/505) \text{ approx.}$$

The mean motion of Mars since the epoch, increased by its epochal position, gives its mean longitude.

MEAN ŚĪGHROCCA OF MERCURY

6 (c-d). 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 Śīghrocca of Mercury since the epoch. (8)

In other words,

$$\text{Mean motion of Śīghrocca of Mercury since the epoch} = 4S + 7S/46,$$

where S is the Dhruvādyarka.

Since (according to Āryabhaṭa I)

$$\frac{\text{mean motion of Śīghrocca of Mercury since the epoch}}{\text{mean motion of the Sun since the epoch}} = \frac{17937020}{4320000}$$
$$= 4 + (7/46) \text{ approx.}$$

therefore,

Mean motion of Śīghrocca of Mercury since the epoch = 4S + 7S/46.

Therefore,

Mean longitude of Śīghrocca of Mercury
= epochal position of Śīghrocca of Mercury + 4S + 7S/46
= epochal position of Śīghrocca of Mercury + 4 (Sun's mean longitude) + 4S/46, neglecting whole revolutions. Hence the rule.

MEAN JUPITER

7 (a-b). The Dhruvādyarka multiplied by 1 and divided by 12, plus the Dhruvādyarka multiplied by 1 and divided by 1032, gives the mean motion of Jupiter since the epoch.

In other words:

Mean motion of Jupiter since the epoch = S/12 + S/1032,

where S is the Dhruvādyarka.

Rationale. According to Āryabhaṭa I,

$$\frac{\text{mean motion of Jupiter since the epoch}}{\text{mean motion of the Sun since the epoch}} = \frac{364224}{4320000}$$
$$= 1/12 + 1/1023 \text{ approx.}$$

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.

MEAN ŚĪGHROCCA OF VENUS

7 (c-d). The Dhruvādyarka multiplied by 10 and divided by 6, minus the

Dhruvādyarka multiplied by 10 and divided by 243, gives the mean motion of the Śīghrocca of Venus since the epoch. (9)

In other words:

Mean motion of Śīghrocca of Venus since the epoch = 10S/6 − 10S/243, where S is the Dhruvādyarka.

This is true, because (according to the Sūrya-siddhānta),

$$\frac{\text{mean motion of Śīghrocca of Venus since the epoch}}{\text{mean motion of the Sun since the epoch}} = \frac{7022376}{4320000}$$
$$= 10/6 - 10/243 \text{ approx.}$$

The mean motion of the Śīghrocca of Venus since the epoch, increased by its epochal position, gives the mean longitude of the Śīghrocca of Venus.

MEAN SATURN

8 (a-b). The Dhruvādyarka multiplied by 1 and divided by 30, plus the Dhruvādyarka multiplied by 6 and divided by 10000, gives the mean motion of Saturn since the epoch.

In other words:

Mean motion of Saturn since the epoch = S/30 + 6S/10000,

where S is the Dhruvādyarka.

Rationale. According to Brahmagupta,

$$\frac{\text{mean motion of Saturn since the epoch}}{\text{mean motion of the Sun since the epoch}} = \frac{146567298}{4320000000}$$
$$= 1/30 + 6/10096 \text{ approx.}$$

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.

MOON'S ASCENDING NODE

8 (c-d). 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. (10)

In other words:

Motion of Moon's ascending node since the epoch = S/20 + S/265,

where S is the Dhruvādyarka.

Rationale. According to Āryabhaṭa I,

$$\frac{\text{motion of Moon's ascending node since the epoch}}{\text{mean motion of the Sun since the epoch}} = \frac{232226}{4320000}$$
$$= 1/20 + 1/266 \text{ approx.}$$

Mañjula takes 1/265 in place of 1/266. Hence the rule.

The motion of the Moon's ascending node since the epoch, subtracted from its position at the epoch, gives the mean longitude of the Moon's ascending node.

It is noteworthy that the rules stated in vss. 8-10 above are exactly the same as those given in the following verses which are found to occur in certain manuscripts of Lalla's Śiṣya-dhī-vṛddhida:

Ravirdvi(2)bhakto ravirāhato nṛpaiḥ (16)
śarābhrabāṇai(505)rhṛtayukkujo'thavā |
Ravirnaga(7)ghno'ṅgayugo(46)ddhṛta-
ścatu(4)rguṇārkayukto bhavatīndujo dhruvaḥ ||
Ravirvibhakto ravi(12)bhirhṛto ravī
radābhracandrai(1032)stridaśādhipo bhavet |
Ravirdaśa(10)ghnādṛtu(6)bhirhṛtāt sitaḥ
punastato rāmajināṃ(243)śavarjitaḥ ||
Ravī rasa(6)ghno'yuta(10000)bhājito bhave-
ddhṛto raviḥ khāgni(30)bhirarkajo'thavā |
Nakho(20)ddhṛto bhāskara iṣvṛtudvi(265)bhi-
rvibhājitaścandraripurvilomagaḥ ||

These verses have not been commented upon by Mallikārjuna Sūri and Bhāskara II, the commentators of Lalla's Śiṣya-dhīvṛddhida, but Sūryadeva Yajvā, in his commentary on LMa (vss. 8-10), definitely ascribes them to Lalla.

The commentator 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 the Sun, Moon, Moon's apogee and ascending node, Mars, Śīghrocca 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 Śīghrocca 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. The commentator Sūryadeva yajvā is also of the same opinion.

Chapter III

TRUE MOTION

KENDRA AND SIGNS OF BHUJA AND KOṬI

1. The longitude of a planet diminished by the longitude of its Ucca, (Mandocca or Śīghrocca), 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).[1] (11)

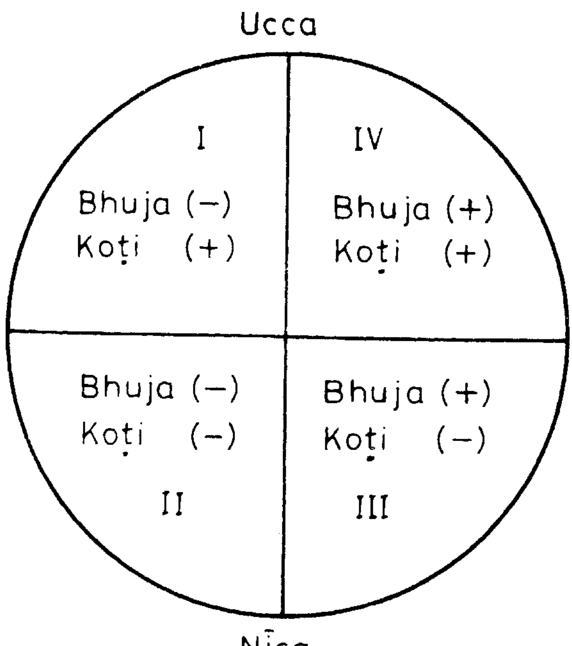
That is to say,

$$\text{Manda-kendra} = \text{Planet} - \text{Mandocca}$$
$$\text{Śīghra-kendra} = \text{Planet} - \text{Śīghrocca}.$$

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 but less than 6 signs, bhuja = 6 signs − kendra; when the kendra is greater than 6 signs but 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 Ucca or Nīca, whichever is nearer.

See infra, vs. 2.

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. This rule is based on the fact that the bhujaphala is negative, negative, positive, and positive and the koṭiphala positive, negative, negative, and positive in the first, second, third, and fourth quadrants, respectively.



BHUJA AND KOṬI

2. 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.[1]

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.[2] (12)

The second half of the text gives the following table of Rsine-differences for R = 8°8′.

Arc	Rsine	Rsine-difference
0	0	
		4° 4′
30°	4° 4′	
		3° 3′
60°	7° 7′	
		1° 1′
90°	8° 8′	

Example. Using this table, 8°8′ sin 80° may be calculated as follows:

$$\begin{aligned} 8°8' \sin 80° &= 8°8' \sin (30° + 30° + 20°) \\ &= 8°8' \sin (\text{1st sign} + \text{2nd sign} + 2/3.\ \text{3rd sign}) \\ &= (4 + 3 + 2/3)° + (4 + 3 + 2/3)' \\ &= 7° 40' + 7' 40'' \\ &= 7° 47' 40''. \end{aligned}$$

Simplified method for calculating Rsine.

The commentators Sūryadeva and Parameśvara have given a simplified method for calculating the value of 8°8′ sin θ according to Mañjula.

1. To calculate 8°8′ sin θ, when θ < 1 sign.
Let $\theta = \alpha° \beta' \gamma''$ Then
$8°8' \sin (\alpha° \beta' \gamma'') = 8(\alpha' \beta'' \gamma''') + 8(\alpha'' \beta''' \gamma'''')$.

2. To calculate 8°8′ sin θ, when 1 sign < θ < 2 signs.
Let $\theta = 1$ sign $\alpha° \beta' \gamma''$. Then
$8°8' \sin (1^s \alpha° \beta' \gamma'') = 4°4' + 6(\alpha' \beta'' \gamma'') + 6(\alpha'' \beta''' \gamma'''')$.

3. To calculate $8°8'\sin\theta$, when 2 signs $< \theta <$ 3 signs.
Let θ = 2 signs $\alpha° \beta' \gamma''$. Then
$8°8'\sin(2^s\alpha°\beta'\gamma'') = 7°7' + 2(\alpha'\beta''\gamma''') + 2(\alpha''\gamma'''\gamma'''')$.

Illustrative Examples.

(1) Calculate $8°8'\sin(4°\ 10'\ 15'')$.
$8°8'\sin(4°\ 10'\ 15'') = 32'\ 80''\ 120''' + 32''\ 80'''\ 120''''$
$= 33'\ 55''\ 22'''$
(Modern value = $35'\ 29''\ 33'''$.)

(2) Calculate $8°8'\sin(1 \text{ sign } 15°\ 40')$.
$8°8'\sin(1 \text{ sign } 15°\ 40') = 4°\ 90'\ 240'' + 4'\ 90''\ 240'''$
$= 5°\ 39'\ 34''$
(Modern value = $5°\ 49'\ 4''$)

(3) Calcuate $8°8'\sin(2 \text{ signs } 10°\ 40')$.
$8°8'\text{sign}(2 \text{ signs } 10°\ 41') = 7°\ 20'\ 80'' + 7'\ 20''\ 80'''$
$= 7°\ 28'\ 41''\ 20'''$
(Modern value = $7°\ 40'\ 32''$)

Mallikārjuna Sūri's true multipliers.

The use of Mañjula's table to 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	3½	½
1st sign	4	4½	4¼	¼
beginning of 1st sign	4½			

Assuming the degrees and minutes of the bhuja to be equal to $\alpha°\beta'$ 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 Mallikājuna Sūri is:

$$\text{true multiplier} = S - \frac{(\alpha°\beta').D}{30}.$$

Thus

$$\text{true multiplier for 1st sign} = 4° \, 15' - \frac{(\alpha°\beta')/4}{30}$$

$$= 4° \, 15' - \frac{\alpha' \, \beta''}{2}$$

$$\text{true multiplier for 2nd sign} = 3° \, 30' - \alpha' \, \beta''$$

$$\text{true multiplier for 3rd sign} = 2° - 2\alpha' \, \beta''.$$

Mallikārjuna Sūri's true multipliers have been actually used in Mss. I_1 and I_2 to obtain the Rsines. Below we give two examples from Ms.I_1.

Example 1. Find 8°8′ sin (1^s 29° 53′ 21″).

Here true multiplier = 3° 30′ − 29′ = 3°1′.

$$\text{Now } \frac{29°53' \times 3°1'}{30} = \frac{29°53' \times 6°2'}{60} = 3° \, 0' \, 17'' \, 46'''.$$

Therefore

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

as stated in the Ms.

(Modern value = 7°2′8″51‴ and Mañjula's value = 7°6′19″26‴).

Example 2. Find 8°8′ sin (1^s 5° 28′ 5″).

Here true multiplier = 3° 30′ − 5′ = 3° 25′.

$$\text{Now } \frac{5°28' \times 3°25'}{30} = \frac{5°28' \times 6°50'}{60} = 37' \, 21'' \, 20'''.$$

Therefore

$$8°8' \sin (1^s 5°28'5'') = 4° \, 37' \, 21'' \, 2''' + 4' \, 37'' \, 21'''$$
$$= 4° \, 41' \, 58'' \, 41'''$$

as stated in the Ms.

(Modern value = 4°43′9″41‴; Mañjula's value = 4°37′21″18‴30⁗).

Bhūdhara's Table. The commentator Bhūdhara gives the following table of Rsines at intervals of 1° for R = 8°8′. Use of this table will give correct values of the Rsines for R = 8°8′.

Table of Rsines. (R = 8°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.)	8½	17	25	34	42	51	59	8	16	25	33	41	49	57	6¼

Degrees	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Rsines	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4
	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	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
	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	5	5	6	6	6	6	6	6	6	6	6	6	6	6	7
	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	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	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	7	7	7	7	8	8	8	8	8	8	8	8	8	8	8
	53	55	57	59	1	2	3	4	5	6	6	7	7	8	8

MANDA-CHEDA OR MANDA DIVISORS

3. The "(manda) divisors" (cheda) 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.[1] (13)

The constants 224 etc. stated above are the values of 60 × 488/r, where r is the value in minutes of the greatest equation of the centre. 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 × 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″

The commentator Sūryadeva Yajvā derives the above values of the manda divisors (manda-chedas) by taking 130′48″, 302′, 651′, 293′, 318′, 91′30″, and 470′ as the greatest equations of the centre 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-cheda, or (madhyama) manda-hāra, and after being corrected by half the corresponding manda-koṭijyā (Rcosine of bhuja) they are called sphuṭa manda-vyāsa, sphuṭa manda-cheda, or sphuṭa manda-hāra.

The term "koṭi" in the text is used in the sense of "koṭijyā". In the present work the terms bhuja and koṭi have been generally used in the sense of bhujajyā and koṭijyā, respectively. See, for example, vss. 14 (c-d) and 18 (a-b).

MANDAPHALA AND MANDA-GATIPHALA

4. 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). (14)

In the case of the Moon, the motion of the apogee amounts to 6′41″ per day, which is not negligible, so the commentator Yallaya suggests that in place of "the mean daily motion of the Moon" one should use "the mean daily motion of the Moon's kendra (or 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 greatest equation of the centre). Then

$$\text{planet's mandaphala} = \frac{R\sin\theta \times r}{R + (R\cos\theta) \times r/2R}, \qquad R = \text{radius}$$

taking the hypotenuse (mandakarṇa) of the planet to be equal to

$$R + (R\cos e\ \theta) \times r/2R^{1}$$

and assuming that the manda epicycle corresponds to this distance,

$$= \frac{488\sin\theta}{488/r + 488\cos\theta/2R}$$

$$= \frac{(8°8'\sin\theta) \times 60}{488/r + (488\cos\theta\ 2R}\ \text{mins.}$$

$$= \frac{(8°8'\sin\theta) \times 60}{60 \times 488/r + (8°8'\cos\theta)/2}\ \text{degrees,}$$

because $60 \times 60/R = 60 \times 60/3438 = 1$ approx.

$$= \frac{(8°8'\sin\theta)\ \text{reduced to minutes}}{\text{manda divisor}}\ \text{degrees.}$$

Also,

$$\text{planet's manda-gatiphala} = \delta\ \frac{(8°8'\sin\theta) \times 60}{\text{manda divisor}}$$

$$= \frac{(8°8'\cos\theta) \times 60}{\text{manda divisor}} . \delta \left(\frac{\theta}{R}\right) \text{degrees}$$

$$= \frac{(8°8'\cos\theta) \times 60 \times 60}{\text{manda divisor}} . \delta \left(\frac{\theta}{R}\right) \text{degrees}$$

$$= \frac{8°8'\cos\theta}{\text{manda divisor}} . \delta\theta\ \text{minutes}$$

$$= \frac{(8°8' \cos\theta) \times \text{mandakendragati}}{\text{manda divisor}} \text{ mins.}$$

$$= \frac{(8°8' \cos\theta) \times \text{madhyamagati}}{\text{manda divisor}} \text{ mins. approx.,}$$

neglecting the motion of the planet's apogee.

Sūryadeva Yajvā's rationale for planet's manda-gatiphala:

True (or true-mean) daily motion

$$= \frac{R \times (\text{mean daily motion})}{H},$$

where H is the planet's hypotenuse or distance

$$= \frac{H - (H - R)}{H}. (\text{mean daily motion})$$

$$= (\text{mean daily motion}) - \frac{\text{koṭiphala} \times (\text{mean daily motion})}{H}$$

$$= \text{mean daily motion} - \frac{(R\cos\theta.r)/R \times (\text{mean daily motion})}{R + (R\cos\theta.r/2R)}$$

$$= \text{mean daily motion} - \frac{(8°8'\cos\theta/R) \times 60 \times 60 \times (\text{mean daily motion})}{8°8' \times 60 \times 60/r + 8°8' \cos\theta \times 60 \times 60/2R}$$

$$= \text{mean daily motion} - \frac{8°8' \cos\theta \times (\text{mean daily motion})}{8°8' \times 60 \times 60/r + 8°8' \cos\theta/2}$$

Therefore,

$$\text{manda gatiphala} = -\frac{8°8' \cos\theta \times \text{mean daily motion}}{\text{manda divisor}} \text{ mins.}$$

Example. Let the Sun's kendra be $6^s1°30'$. Then

bhuja = 1°30'.	koṭi = − 2^s 28° 30'
bhujayā = 8(1°30″) + 8(1″30‴)	koṭijyā = − (4°4' + 3°3') + 56' 60″ + 56″60‴
= 12' 12″	= − (7°7' + 57'57″)
= 12' approx.	= − 8°4'57″ = − 8° approx.

Therefore,

$$\text{Sun's mandaphala} = \frac{\text{bhujajyā reduced to minutes}}{224 + \text{koṭijyā}/2}$$

$$= \frac{12}{224-4} \text{ degrees}$$

$$= \frac{12}{220} \text{ degrees}$$

$$= 3' \text{ approx.}$$

$$\text{Sun's true kendra} = 6^{s}1^{\circ}30' + 3' = 6^{s}\ 1^{\circ}33'$$

$$\text{Sun's gatiphala} = \frac{\text{koṭijyā} \times \text{Sun's mean daily motion}}{224 + \text{koṭijyā}/2}$$

$$= \frac{8 \times 59'8''}{224-4}$$

$$= \frac{473}{220} \text{ or } 2'9''.$$

Therefore,

$$\text{Sun's true daily motion} = 59'8'' + 2'9'' = 61'17''$$
$$= 61' \text{ approx.}$$

Mallikārjuna Sūri's interpretation.

Mañjula's formula for the planet's mandaphala clearly shows that Mañjula has applied hypotenuse proportion in finding the planet's mandaphala which is against the teachings of the Hindu astronomers in general. If the hypotenuse proportion is not applied Mañjula's formula would take the form:

$$\text{planet's mandphala} = \frac{(8^{\circ}8' \sin\theta) \text{ reduced to minutes}}{60 \times 488/r} \text{ degrees,}$$

where θ is the planet's mean anomaly and r the radius of the planet's manda epicycle.

If this formula is used, we will have

$$\text{Sun's mandaphala} = \frac{(8^{\circ}8' \sin\theta) \text{ reduced to minutes}}{224} \text{ degrees,}$$

θ being the Sun's mean anomaly reduced to bhuja, and

$$\text{Moon's mandaphala} = \frac{(8°8'\sin\theta')\text{ reduced to minutes}}{97}\text{ degrees},$$

θ' being the Moon's mean anomaly reduced to bhuja.

The formula for the planet's manda-gatiphala will consequently take the form:

$$\text{planet's mandagatiphala} = \frac{(8°8'\cos\theta) \times \text{madhyamagati}}{60 \times 488/r}\text{ mins.},$$

where θ is the planet's mean anomaly reduced to bhuja and r the radius of the planet's manda epicycle.

It was Mallikārjuna Sūri who first raised objection to the use of the hypotenuse-proportion by Mañjula, at least in the case of the Sun and Moon, in finding the mandaphala and mandagatiphala. He interpreted Mañjula's rules following the general trend of Hindu astronomy. He is reported to have written:

> "Chedā jināśvino'gāṅkā" ravīndvoḥ sphuṭakarmaṇi |
> Gatisphuṭārthamarkendvośchedau tāveva mānase ||
> Koṭyardhasaṃskṛtau chedau ravindvorbimbasādhane |

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 as corrected by half the (manda) koṭijyā are meant to be used in 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:

$$\text{Sun's mandaphala} = \frac{(8°8'\sin\theta)\text{ reduced to mins.}}{224}\text{ degrees}$$

$$\text{Sun's mandagatiphala} = \frac{(8°8'\cos\theta) \times \text{Sun's mean daily motion}}{224}\text{ mins.}$$

θ being the Sun's mean anomaly reduced to bhuja; and the following formulae in the case of the Moon:

$$\text{Moon's mandaphala} = \frac{(8°8'\sin\theta)\text{ reduced to mins.}}{97}\text{ degrees}$$

$$\text{Moon's mandagatiphala} = \frac{(8°8' \cos\theta) \times \text{Moon's mean daily motion}}{97} \text{ mins.}$$

θ′ being the Moon's mean anomaly reduced to bhuja.

The commentator Yallaya has mentioned the views of Mallikārjuna Sūri as follows:

Mallikārjunasūriṇā ravicandrayoḥ phalānayane (gatiphalānayane) ca koṭyardhasaṃskṛtau chedau na bhavataḥ bimbasādhane koṭyardhasaṃskṛtau chedau syātāmityuktam. Tathā'sya sārdhaślokau likhyante —

"Chedā jināśvino'gāṅkā" ravīndvoḥ sphuṭakarmaṇi ।
Gatisphuṭārthamarkendvośchedau tāveva mānase ॥
Koṭyardhasaṃkṛtau chedau ravīndvorbimbasādhane ।

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 as corrected by half the (manda) koṭijyā are meant to be used in the case of finding the diameters of the discs of the Sun and Moon."

The commentator Bhūdhara, following Mallikārjuna Sūri, says:

Koṭyardhasaṃskṛtau chedau ravīndvorbimbasādhane ।
Gatisphuṭārthamarkendvośchedau tāveva mānase ॥
iti paribhāṣayā atra na koṭyardhasaṃskāraḥ.

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 the case of finding the true positions and true daily motions of the Sun and Moon the same divisors (uncorrected by half the manda koṭijyā) 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 true position and true daily motion of the Moon he has used the divisor 97 without correcting it by half the manda koṭijyā.

The 1½ verses ascribed above to Mallikārjuna Sūri occur also in Mss. H_1 and H_2. They are also found to be interpolated in the text of Ms. A_1 giving the text along with the commentary of Praśastidhara. So it seems they were quite popular amongst the users of the Laghumānasa.

ŚĪGHRA-VYĀSA OR ŚĪGHRA DIVISORS

5. 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). (15)

6. 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 Śīghrocca and the other (slower one) the planet.[1] (16)

That is to say,

Śīghra divisor = Śīghra Vyāsa + Śīghra-bhujajyā/3 ± Śīghra-koṭijyā,

where the Śīghra Vyāsas of the planets are given by the following table:

Śīghra Vyāsas of the Planets

Planet	Śīghra Vyāsa (or Madhyama Śīghra Vyāsa)
Mars	(45 + mandakoṭijyā/2) × 4/15
Mercury	100 × 7/33 or 21
Jupiter	(92 + mandakoṭijyā/2) × 3/7
Venus	320 × 1/29 or 11
Saturn	(63 + mandakoṭijyā/2) × 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 śīghrakendra reduced to bhuja and r' minutes the radius of the planet's śīghra epicycle. Then

$$\text{planet's śīghraphala} = \frac{R\sin\theta' \times r'}{R \pm \text{śīghrakoṭiphala}}, \qquad (1)$$

taking the śīghra-karṇa to be equal to R ± śīghra-koṭiphala.

[1] Cf. vss. 5-6 (a-b) with KA, i. 29½-33. Vs. 6 (c-d) is the same as KA, i. 20½ (a-b).

$$= \frac{R\sin\theta' \times r'}{R \pm \dfrac{R\cos\theta' \times r'}{R}}$$

$$= \frac{488\sin\theta'}{488/r' \pm 488\cos\theta'/R} \text{ mins.}$$

$$= \frac{8°8' \sin\theta' \times 60}{60 \times 488/r \pm 8°8'\cos\theta'} \text{ degrees,}$$

because $60 \times 60/R = 1$ approx.

Mañjul.. replaces the first term in the denominator, viz. $60 \times 488/r'$, by

$$\left[\frac{60 \times 488}{r} + \frac{\text{mandakoṭiyā}}{2} \frac{r}{r'} + \frac{\text{śīghrabhujajyā}}{3} \right]$$

$$\text{or śīghra-vyāsa} + \frac{8°8' \sin\theta'}{3},$$

and so he takes

$$\text{śīghra-phala} = \frac{8°8'\sin\theta' \times 60}{\text{śīghravyāsa} \times 8°8' \sin\theta/3 \pm 8°8' \cos\theta'}$$

$$= \frac{8°8' \sin\theta' \times 60}{\text{śīghra divisor}}, \qquad (2)$$

where

śīghra divisor = śīghravyāsa + $8°8' \sin\theta/3 \pm 8°8' \cos\theta'$.

Formula (2) was probably supposed to yield better result, agreeing with observation, than formula (1).

When mandakendra is equal to 90°, the śīghra-vyāsas of the planets take the following values:

Planet	Śīghra-vyāsa
Mars	12°
Mercury	21°
Jupiter	39°26′
Venus	11°
Saturn	73°

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

$$\frac{60\times 488}{r} + \frac{\text{śīghrabhujajyā}}{3},$$

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°, then the śīghra vyāsas obtained will be as shown in the following table:

Planet	r′	śīghravyāsa (= 488 × 60/r′)
Mars	1968′	12°
Mercury	1207′	21°33′
Jupiter	676′	40°35′
Venus	2132′	10°57′ or 11°
Saturn	380′	74°20′

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

$$\text{śīghravyása} + \frac{8°8' \sin\theta'}{3}$$

Using this term,

$$\text{śīghra divisor} = \text{sphuṭa śīghravyāsa} + 8°8' \cos\theta'.$$

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 śighra divisor, Mañjula makes the correction of śīghra koṭijyā and not of half the śīghra koṭīijyā, N.K. Majumdar thinks that the correction of half the manda koṭijyā in finding the manda divisor may be an error. This is 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 Śighrocca of a planet. The Śighrocca 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.

Śighroccas of the planets

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

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

TRUE DAILY MOTION OF A PLANET

7. Subtract one-twelfth of the śighraphala from the (śighra) vyāsa; then multiply that by the difference between the (true-mean) daily motion of the planet and the daily motion of its Śighrocca; then divide that by the śighra divisor; and then subtract that from the daily motion of the Śighrocca: the result is the true daily motion (of the planet). (17)

That is,

$$\text{true daily motion} = \text{Śighrocca-gati} - \frac{(\text{śīghra-vyāsa} - \text{śīghraphala}/12) \times \text{śīghrakendragati}}{\text{śīghra divisor}}$$

where $\text{śīghrakendragati} = \text{daily motion of śīghrocca} - \text{true-mean daily motion of the planet.}$

This formula has been derived, according to the commentator Sūryadeva Yajvā, as follows:

Since

true daily motion = śīghroccagati − sphuṭakendragati, and

$$\text{sphuṭakendragati} = \frac{\text{radius} \times \text{śighrakendragatijyā}}{\text{śighra hypotenuse}}$$

$$\text{sphuṭa sphuṭakendragati} = \frac{\text{śīghra-vyāsa} \times \text{śighrakendragatijyā}}{\text{śīghra divisor}}$$

$$= \frac{(\text{sphuta śīghra-vyāsa} - \text{śighraphala}/12) \times \text{śīighrakendragati}}{\text{śīghra divisor}}$$

Hence the rule.

Sūryadeva Yajvā explains as follows: "Here in the case of śīghra-correction the position is as follows: When the Śighrocca 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 Śīghrocca each, in a civil day, move eastward through a distance equal to their own daily motions. Now the Śīghrocca 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 the daily motions of the true mean planet and the Śīghrocca, appears to hang down (by that distance) towards the west. This is why the daily motion of the Śīghrocca minus the daily motion of the true-mean planet gives the daily motion of the śīghrakendra. And similarly every day by subtracting the daily motion of the true-mean planet from the daily motion of the Śīghrocca 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 been made true and then subtracting it from the daily motion of the Śīghrocca one gets the true daily motion of the planet. Here the Ācarya has taken recourse to this second method. Hence the proportion intended by the ācarya is: When the Concentric (Kakṣāvrītta) yields this śīghrakendragati what will the Eccentric yield? This is the inverse proportion, because when the hypotenuse (śīghrakarṇa) increases the śīghrakendragati decreases and when the hypotenuse decreases the śīghrakendragati increases. Here 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, subtraction is made reversely and the remainder obtained is the retrograde motion (vakragati). Here subtraction 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 bhujāphala, 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 śighraphala."

Citrabhānu (A.D. 1530), the author of the Karaṇāmṛta, has prescribed the following rule for finding the true daily motion of a planet:[1]

$$\text{true daily motion} = \text{śīghragati} - \frac{(\text{śīghravyāsa-śīghraphala}/14) \times \text{śīghrakendragati}}{\text{śīghra divisor}}$$

[1]See KA, i. 35-36.

Chapter IV
MISCELLANEOUS TOPICS

1. SECOND CORRECTION FOR THE MOON
(Evection plus Part of Moon's equation of the centre)

1-2. Multiply the degrees of the Moon's (true) daily motion[1] 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 subtractive 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.[2] (18-19)

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

$$= 8°8' \cos (S - U) \text{ [Moon's true daily motion in degrees} - 11] \times 8°8' \sin (M - S), \quad \ldots(1)$$

which is negative or positive according as

$$8°8' \cos (S - U) \text{ and } 8°8' \sin (M - S)$$

are of unlike or like signs; and the corresponding correction for the Moon's true daily motion

$$= 8°8' \cos (S - U) \text{ [Moon's true daily motion in degrees} - 11] \times 8°8' \cos (M - S)/5, \quad \ldots (2)$$

which is positive or negative according as

$$8°8' \cos (S - U) \text{ and } 8°8' \cos (M - S)$$

[1] Following the commentators, we have translated the word "gatyaṃśa" as meaning "the degrees of the Moon's (true) daily motion". D. Mukhopadhyaya, P.C. Sengupta, and N.K. Majumdar, however, have translated this word as meaning "the degrees of the Moon's (mean) daily motion". See D. Mukhopadhyaya, (1930), Bull. Cal. Math. Soc., 22, 121-32; P.C. Sengupta, (1932), Bull. Cal. Math. Soc., 24, 1-18; and N.K. Majumdar, (1951), Laghumanasam, p. 67.

[2] The same rule occurs in the Karaṇa-kamala-mārtaṇḍa of Daśabala (A.D. 1058). See KKM, ii. 46 (c-d)-49 (a-b).

are of unlike or like signs.[1]

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 daily motion, respectively.

Expression (2) is clearly an approximate value of the differential of (1); for

$$\delta[8°8' \sin(M - S)] = 8°8' \cos(M - S) \,.\, \delta[M - S)/R], \text{ R being the radius}$$
$$= \frac{8°8' \cos(M - S)}{5},$$

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

$$\begin{aligned} & 8°8' \times 8°8' \times 2°11' \cos(S - U) \sin(M - S) \\ = & \; 66°9' \times 2°11' \cos(S - U) \sin(M - S) \\ = & \; 144°26' \cos(S - U) \sin(M - S). \qquad \ldots (3) \end{aligned}$$

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[1]

$$\begin{aligned} & 377' \sin(nt-\alpha) + 13' \sin 2(nt-\alpha) + \ldots \\ & \quad + 76\alpha \sin[2(nt-\dot{S}) - (nt-\alpha)] + 40' \sin 2(nt-S) + \ldots \end{aligned}$$

where nt is the Moon's mean longitude, α the longitude of the Moon's perigee, and S the Sun's longitude.

In this expression

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

[1] 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 with observation, but not in finding tithi, karaṇa, nakṣatra and yoga.

[2] The accurate values of the coefficients are 377′ 19″·06, 12′57″·11, 76′26″ and 39′30″.

$$76' \sin[2(nt-S) - (nt-\alpha)]$$ is called the evection,
and $40' \sin 2(nt-S)$ is called the variation.

The early Hindu astronomers recognised 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

$$301' \sin(nt-\alpha) + 13' \sin 2(nt-\alpha) + \\ + 76' \sin(nt-\alpha) + \sin[2(nt-S) - (nt-\alpha)] + \\ + 40' \sin 2(nt-S) + \ldots\ldots$$

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

or, in the notation of formula (1),

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

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 (A.D. 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. This 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.[1]

In Greek Astronomy

The Greek astronomer Claudius Ptolemy (c. A.D. 100 to c. A.D. 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 equalled 90° and S – U was either zero or 180°, and that it vanished altogether when M – S equalled zero or 180°.

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[2] of Daśabala (A.D. 1058), evidently under the influence of Mañjula. Subsequently, it appears in different but equivalent forms in the Siddhānta-śekhara[3] of Śrīpati (c. A.D. 1039), the Tantra-saṅgraha[4] of Nīlakaṇṭha (A.D. 1500), the Uparāga-kriyākrama[5] of Nārāyaṇa (A.D. 1563), the Karaṇottama[6] of Acyuta (d. A.D. 1621), and the Siddhānta-darpaṇa[7] of Sāmanta Candra Śekhara Singh (A.D. 1869).[8]

2. CORRECTION FOR LOCAL LONGITUDE

3. By the distance (in yojanas) of the local place, east or west of the meridian of Avantī, multiply the 60th part of the degrees of the planet's daily motion; subtract the resulting minutes from or add them to the longitude of the planet (according as the local place is to the east or to the west of the meridian of Avantī). (20)

1. See, for example, Ā, iv. 48.
2. ii. 46 (c-d)-49 (a-b).
3. xi. 2-4.
4. viii. 1-3.
5. iv. 7-9.
6. ii. 15-16.
7. Grahagaṇita, vi. 7-10 (a-b).
8. For further details, see my paper entitled "The evection and the deficit of the equation of the centre of the Moon in Hindu Astronomy" in Proceedings of the Benares Mathematical Society, New Series, Vol. VII, No. 2, Dec. 1945.

That is,

$$\text{longitude-correction} = \pm \frac{d \times m}{60} \text{ mins.,}$$

where d denotes 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 evidently takes the equatorial circumference of the Earth as equal to 3600 yojanas and applies the proporation: "When 60 m minutes of the planet's daily motion correspond to 3600 yojanas, how many minutes of the planet's motion will correspond to d yojanas?" The result is the minutes of the longitude-correction for the planet.

The rule is approximate in so far as the local circumference of the Earth has been taken to the equal to the equatorial circumference of the Earth.

The commentator Yallaya gives a different reading of the text, viz.

> Avantisamayāmyodag rekhāpūrvaparādhvanā ।
> Hatā bhuktiḥ khakhāṣṭābdhihṛtā liptāsvṛṇaṃ dhanam ॥

which may be translated as follows:

> "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; subtract 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)."[1]

Here the equatorial circumference of the Earth has been assumed to be equal to 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, the following places are situated on it:

Laṅkā, Kumārikā, Kāñchī, Pāṭalī, Siddhapurī, Vatsagulma, Ujjayinī, Lohītaka, Kuru, Yamunā, and Meru.

Laṅkā is a hypothetical place in 0 latitude and 0 longitude. Kumārikā is the same as Kanyā Kumārī (modern Cape Camorin). Kāñcī is Conjeevaram. Vatasagulma is Basim. Lohītaka is Rohtak. Kuru is Kurukṣetra. Yamunā is Yamunānagara. Meru is north pole. Pāṭalī and Siddhapura remain unidentified.

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[1]Cf. KKM, ii. 1-2 (a-b).

The following are the mean daily motions of the planets as stated by Yallaya and the Mysorean commentator:

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 asc. node	−3′11″
Jupiter	5′00″		

3. TITHI, KARAṆA, NAKṢATRA, AND YOGA

4. 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 nad end from their own daily motions, by applying proportion. (31)

The tithi, vāra ("day"), nakṣatra, karaṇa, and yoga constitute the five elements of the Hindu Pañcāṅga.

Let S be the Sun's longitude and M the Moon's longitude. Also led d be the difference and s the sum of the 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 new moon and the beginning of the first tithi; when $M-S=12°$, the first tithi ends and the second begins; when $M-S=24°$, 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 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 Pūrṇimāsī, 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′ 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 a gives the ghaṭīs etc. elapsed since the beginning of the current tithi. The same remainder subtracted from 720, when multiplied by 60 and divided by d gives the ghaṭīs etc. to elapse before the end of the 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 $M\text{-}S=0$; the second when $M\text{-}S=6°$; the third when $M\text{-}S=12°$; and so on. The first karaṇa is called Kimstughna, the 58th is called Śakuni, a cycle of 7 karaṇas called Bava (or Baba), Bālava, Kaulava, Taitila, Gara, Vaṇija, and Viṣṭi (respectively) repeats itself 8 times. These seven karaṇas are called movable karaṇas. Of these karaṇas, Viṣṭi (also called Bhadrā) is considered to be inauspicios and no auspicious deed is done in its duration.

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 a gives the ghaṭīs etc. elapsed since the beginning of the current karaṇa. The same remainder subtracted from 360, when multiplied by 60 and divided by a gives the ghaṭīs etc. to elapse before the end of the current karaṇa.

Nakṣatra Beginning with the first point of the nakṣatra Aśvinī (or star Zeta Piscium), the ecliptic is divided into 27 equal parts each equal to 800 minutes of arc. These parts are called nakṣatra and bear the names: (1) Aśvinī, (2) Bharaṇī, (3) Kṛttikā, (4) Rohinī, (5) Mṛgaśirā, (6) Ārdrā, (7) Punarvasu, (8) Puṣya, (9) Āśleṣā, (10) Maghā, (11) Pūrvā Phālgunī, (12) Uttarā Phālgunī, (13) Hasta, (14) Citrā, (15) Svātī, (16) Viśākhā, (17) Anurādhā, (18) Jyeṣṭhā, (19) Mūla, (20) Pūrvāṣādhā, (21) Uttarāṣādhā, (22) Śravaṇa, (23) Dhaniṣṭhā, (24) Śatabhiṣak, (25) Pūrvā Bhāndrapadā, (26) Uttarā Bhādrapadā, and (27) Revatī.

To compute the nakṣatra, reduce the longitude of the desired planet to minutes and divided 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 days etc. elapsed since the planet entered into the current nakṣatra. The same remainder subtracted 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 Pañcāngas give the Moon's nakṣatra.

Yoga The yogas are also 27 in number and bear the neames: (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) Varīyān, (19) Parigha, (20) Śiva, (21) Sādhya, (22) Siddha, (23) Śubha, (24) Śukla, (25) Brahmā, (26) Indra, and (27) Vaidhṛta.

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 minutes of arc and divide by 800. The quotient gives the number of yoga elapsed, and the remainder multiplied by 60 and divided by a gives the ghaṭīs etc. elapsed since the beginning of the current yoga. The same remainder subtracted from 800, when multiplied by 60 and divided by s, gives the ghaṭīs etc. to elapse before the end of the current yoga.

Chapter V
THE THREE PROBLEMS

The astronomers are not unanimous regarding the three problems. According to Bhaṭṭotpala[1], the three problems relate to lagna ("rising point of the ecliptic"), kāla ("time corresponding to lagna"), and chāyā ("gnoomonic shadow"). According to Bhūdhara[2], they relate to lagna, chāyā, and cara ("twice the ascensional difference"). But generally they are supposed to relate to dik ("the cardinal directions"), deśa ("latitude of the local place"), and kāla ("time"). In the present chapter, Mañjula deals with cara, lagna, and chāyā.

CARAS OR TWICE THE ASCENSIONAL DIFFERENCES OF SIGNS, AND SUN'S CARA.

1. The equinoctial midday shadow (viṣuvacchāyā 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 cara (i.e., twice the Sun's ascensional difference)[3]. (22)

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 (muliplier), and the third by the third (multiplier). Having multiplied them separately, find their sum. What results are the vināḍīs of the Sun's cara."

Example. The tropical longitude of the Sun is 8 signs 25°. Find the Sun's cara for a place where palabhā = 6 aṅgulas..

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

Sun's cara = cara of first sign + cara of second sign
+ cara of third sign × 25/30 vināḍīs
= 120 + 96 + 40 × 25/30 vināḍīs
= 216 + 100/3 vināḍīs
= 249⅓ vināḍīs.

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

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[1] See his com. on KK, iii. opening lines.
[2] See his commentary on LMā, tripraśnādhikāra, opening lines.
[3] Cf. KK, iii. 1; KA, i. 38.

cara for Aries = 20 × palabhā vināḍīs
cara for Taurus = 20 × palabhā (1 − 1/5) vināḍīs
cara for Gemini = 20 × palabhā/3 vināḍīs.

The Sun's cara (or cara for the Sun) means the difference between the durations of daylight at the local place and the equator, or twice the Sun's ascensional difference.

In general, the cara 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 cara for the sign Aries means the difference between the cara for the last point of Aries and the cara for the first point of Aries. The cara for the sign Taurus means the difference between the cara for the last point of Taurus and the cara for the first point of Taurus. Similarly, the cara for the sign Gemini means the difference between the caras for the last and first points of Gemini.

The term palabhā means the equinoctial midday shadow of a gnomon of 12 aṅgulas (digits). The term viṣuvacchāyā used in the Sanskrit text is a 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 caṣaka.

OBLIQUE ASCENSIONS OF THE SIGNS

2. 278, 299, and 323 written in this 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 the 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)[1]. (23)

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 ascensionals 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:

[1] Same rule occurs in RāMṛ, iii. 1-2.

Sign	oblique ascension in vināḍis	Sign	oblique ascension 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

LAGNA AND IṢṬANĀḌĪS

3. 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 question, 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.[1] (24)

This gives the usual methods for finding the lagna and the iṣṭakāla. Bhāskara I has given these methods in greater detail. See MBh, iii. 30-32 and 33.

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

DAY-LENGTH AND NATAKĀLA (HOUR ANGLE)

4. The vināḍīs of the Sun's cara (i.e., twice 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.[2] (25)

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 = nāḍīs + twice the Sun's ascensional difference (in vināḍīs).

[1]Cf. KK, iii. .5.
[2]Same as KA, ii. 1.

The word "reversely" in the text is meant to say that the vināḍīs of the Sun's cara should be added when the sign of the Sun's cara is negative, and subtracted when the sign of the Sun's cara is positive, the sign of the Sun's cara being the same as the sign of the Sun's bhuja. That is, addition of the vināḍīs of the Sun's cara should be made when the Sun is in the northern hemisphere and subtraction 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.

MIDDAY SHADOW

5. The cara (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.[1] (26)

That is,

midday shadow

$$= \frac{\text{caravināḍīs of 1st sign} \mathbin{\substack{\sim\\+}} \dfrac{5.\ \text{Sun's carārdha-vināḍīs}}{\text{palabhā}}}{\text{nāḍīs of day-length} - 10} \text{ angulas,}$$

$\sim$ or $+$ sign being taken according as the Sun is in the northern or southern hemisphere.

Rationale. Let ϕ be the local latitude, δ the Sun's declination, and a, z the Sun's altitude and zenith distance at midday. Then

$$z = \phi \mp \delta,$$

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

$$\therefore \text{Rsin } z = \frac{\text{Rsin}\phi.\text{Rcos}\delta \mp \text{Rcos}\phi.\text{Rsin}\delta}{\text{R}}$$

$$= \frac{\text{palabhā. Rcos}\delta \mp 12.\ \text{Rsin }\delta}{\text{palakarṇa}} \qquad (1)$$

$$\text{because } \frac{\text{Rsin}\phi}{\text{palabhā}} = \frac{\text{Rcos}\phi}{12} = \frac{\text{R}}{\text{palakarṇa}} \qquad (1)$$

[1]Same rule occurs in SiSaṁ, iii. 9 (c – d)-12 (a – b).

$$\therefore \text{ midday shadow} = \frac{12.\text{Rsin } z}{\text{Rsin } a} = \frac{\text{palakarṇa} \times \text{Rsin } z}{\text{midday hṛti}}$$

$$= \frac{\text{palakarṇa} \times \text{Rsin } z}{\text{Rcos}\delta \pm \text{earthsine}}$$

$$= \frac{\text{palabhā} \times \text{Rcos}\delta \mp 12 \times \text{Rsin}\delta}{\text{Rcos}\delta \pm \text{earthsine}}, \text{ using} \qquad (1)$$

$$= \frac{\text{R. palabhā} \mp \dfrac{12.\text{R.Rsin}\delta}{\text{Rcos}\delta}}{\text{R} \pm \text{carārdhajyā}}$$

$$= \frac{\text{R. palabhā} \mp \dfrac{12.12.\text{carārdhajyā}}{\text{Rcos}\delta}}{\text{R} + \text{carārdhajyā}},$$

$$\text{because } \frac{\text{R}}{\text{Rcos}\delta} \cdot \frac{\text{palabhā} \times \text{Rsin}\delta}{12} = \frac{\text{R}}{\text{Rcos}\delta} \times \text{earthsine}$$

$$= \text{carārdhajyā}$$

$$= \frac{\text{R. palabhā} \mp \dfrac{12.12.6.\text{carādhavināḍīs}}{\text{palabhā}}}{\text{R} \pm \dfrac{\text{caranaḍī}.6.60}{2}}$$

$$= \frac{20.\text{ palabhā} \pm \dfrac{12.12.6.20.\text{ carādhavināḍīs}}{\text{R. palabha}}}{20 \mp \dfrac{\text{caranāḍ} \times 6.60.20}{2\text{R}}}$$

$$= \frac{20.\text{palabhā} \mp \dfrac{5.\text{ carādhavināḍīs}}{\text{palabha}}}{20 \mp \text{caranāḍī}}$$

$$= \frac{20.\text{ palabhā} \mp \dfrac{5.\text{ carādhavināḍīs}}{\text{palabha}}}{(30 \pm \text{caranāḍī}) - 10}$$

$$= \frac{20.\ \text{palabhā} \mp \dfrac{5.\ \text{carādhavināḍīs}}{\text{palabhā}}}{\text{nāḍīs of day-length} - 10} \text{ angulas}$$

$$= \frac{\text{caravināḍīs of 1st sign} \mp \dfrac{5.\ \text{carādhavināḍīs}}{\text{palabha}}}{\text{nāḍīs of day-length} - 10} \text{ angulas.}$$

Alternative Rationale.

Midday shadow $= 12 \tan z = 12 \tan (\phi \mp \delta)$,

(according as the Sun is in the northern or southern hemisphere)

$$= \frac{12 (\tan \phi \mp \tan \delta)}{1 \pm \tan \phi . \tan \delta}$$

$$= \frac{240 \tan \phi \mp 240 \tan \delta}{20 \pm 20 \tan \phi . \tan \delta}$$

$$= \frac{20.12 \tan\phi \mp \dfrac{5.3438.\ \tan\phi.\tan\delta}{6.12.\tan\phi}}{20 \pm 20 \tan\phi.\tan\delta}$$

$$= \frac{20.\ \text{palabhā} \mp \dfrac{5.\text{R}\tan\phi.\tan\delta}{6.\text{Palabha}}}{30 \pm 20 \tan\phi.\tan\delta - 10}$$

$$= \frac{20.\ \text{palabhā} \mp \dfrac{5.\ \text{carārdhavināḍīs}}{\text{palabhā}}}{(30 \pm \text{caranāḍīs}) - 10},$$

because caranāḍīs $= \dfrac{2\text{R}\tan\phi.\tan\delta}{60.6}$
$= 20.\tan\phi.\tan\delta$

$$= \frac{20.\text{palabhā} \mp \dfrac{5.\text{carārdhavināḍīs}}{\text{palabhā}}}{\text{nāḍīs of day-length} - 10} \text{ aṅgulas.}$$

SHADOW FOR THE GIVEN TIME

6-7. 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 the 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.[1] (27-28)

That is:

$$\text{Desired shadow} = \frac{\sqrt{[(M + D) \times 12^2 + (M \times \text{midday} - \text{shadow})^2]}}{D} \text{ aṅgulas,'}$$

where

$$\text{multiplier } M = \frac{(\text{day-length} - 10) \times 9}{N^2} + \frac{\text{day-length} - 10}{100},$$

$$\text{divisor } D = M - 1,$$

and given natakāla = N.

Rationale.

This rule is based on the formula:

$$\text{desired shadow} = \sqrt{[(\text{hypotenuse of desired shadow})^2 - 12^2]}. \qquad (1)$$

Since

hypotenuse of desired shadow

$$= \frac{\text{hypotenuse of desired shadow}}{\text{hypotenuse of midday shadow}} \times \text{hypotenuse of midday shadow}$$

$$= \frac{M}{M - 1} \times \text{hypotenuse of midday shadow}$$

[1]Same rule occurs in RāMṛ, iii. 19-22 (a – b); GGB, iv. 8-10 (a – b); SiSaṃ, iii. 16-18a.

$$M = \frac{\text{hypotenuse of desired shadow}}{\text{hypotenuse of desired shadow} - \text{hypotenuse of a midday shadow}}$$

$$= \frac{\dfrac{R\times 12}{R\sin a}}{\dfrac{R\times 12}{R\sin a} - \dfrac{R\times 12}{R\cos(\phi-\delta)}}$$

where ϕ is the local latitude, δ the Sun's declination, a the Sun's altitude, and R the radius, the Sun being assumed to be in the northern hemisphere.

$$= \frac{\cos(\phi\sim\delta)}{\cos(\phi\sim\delta) - \sin a}$$

$$= \frac{\cos\phi.\cos\delta + \sin\phi.\sin\delta}{\cos\phi.\cos\delta + \sin\phi.\sin\delta - (\sin\phi.\sin\delta + \cos\phi.\cos\delta.\ \cos N)}$$

because applying cosine formula to the spherical triangle ZPS in which Z is the zenith, P the north pole, S the Sun, arc ZS $= 90° - a$, arc ZP $= 90° - \phi$, arc PS $= 90° - \delta$, and angle ZPS $=$ N, we have $\sin a = \sin\phi.\ \sin\delta + \cos\phi.\cos\delta.\cos N$.

$$= \frac{\cos\phi.\cos\delta + \sin\phi.\sin\delta}{\cos\phi.\cos\delta - \cos\phi.\cos\delta.\ \cos N} = \frac{1 + \tan\phi.\tan\delta}{1 - \cos N}$$, N being in nāḍīs

$$= \frac{1 + \tan\phi.\tan\delta}{1 - \sin(90-6N)^\circ} = \frac{1 + \tan\phi.\tan\delta}{1 - \dfrac{4\,(90+6N)\,(90-6N)}{40500 - (90+6N)\,(90-6N)}},$$

using Bhāskara 1's formula: $\sin\theta^\circ = \dfrac{4\,(180-\theta)\theta}{40500 - (180-\theta)\theta}$

$$= \frac{1 + \tan\phi.\tan\delta}{1 - \dfrac{4\,(15+N)\,(15-N)}{1125 - (15+N)\,(15-N)}}$$

$$= \frac{(1 + \tan\phi.\tan\delta)\,[1125 - (225-N^2)]}{1125 - (225 - N^2) - 4\,(225 - N^2)}$$

$$= \frac{(1 + \tan\phi.\tan\delta)(900 + N^2)}{5 N^2}$$

$$= \frac{(20 + 20\tan\phi.\tan\delta)(900 + N^2)}{100N^2}$$

$$= \frac{(20 + \text{caranāḍīs})(900 + N^2)}{100N^2}$$

because cara $= 2 \tan\phi.\tan\delta$ radians

$= 2R. \tan\phi. \tan\delta$ mins.

$= \frac{2R.\tan\phi.\tan\delta}{360}$ nāḍīs

$= 20\tan\phi.\tan\delta$ nāḍīs approx.

$$= \frac{[(30 + \text{caranāḍīs}) - 10](900 + N^2)}{100N^2}$$

$= \frac{(d - 10)(900 + N^2)}{100N^2}$, where d = day-length in nāḍīs

$$= \frac{(d - 10) \times 9}{N^2} + \frac{d - 10}{100},$$

therefore, from (1), we have

desired shadow $= \sqrt{\{[\frac{M}{M-1} \times (\text{hypotenuse of midday shadow})]^2 - 12^2\}}$

$$= \frac{\sqrt{\{M^2 (\text{hyp. of midday shadow})^2 - 12^2 (M-1)^2\}}}{M-1}$$

$$= \frac{\sqrt{\{M^2 [(\text{midday shadow})^2 + 12^2] - 12^2 (M-1)^2\}}}{M-1}$$

$$= \frac{\sqrt{\{12^2 [M^2 - (M-1)^2] + M^2 (\text{midday shadow})^2\}}}{M-1}$$

$$= \frac{\sqrt{\{(2M-1).12^2 + (M \times \text{midday shadow})^2\}}}{D},$$

where $M = \frac{(d-10).9}{N^2} + \frac{d-10}{100}$, and $D = M - 1$.

Note. When the Sun is in the southern hemisphere, the rationale is similar.

HYPOTENUSE OF SHADOW

8(a-b). 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).[1] (29ab)

That is,

$$\text{hypotenuse of shadow} = \sqrt{[(\text{shadow})^2 + 12^2]}$$

and

$$\text{shadow} = \sqrt{[(\text{hypotenuse of shadow})^2 - 12^2]}.$$

NATAKĀLA OR HOUR ANGLE

8(c-d)-9. Divide the hypotenuse of the given shadow by the hypotenuse of the given shadow minus 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).[2] (29cd-30)

That is,

$$\text{Natakāla} = \sqrt{\left[\frac{9(\text{day-length} - 10)}{M - \frac{\text{day-length} - 10}{100}}\right]} \text{ nāḍīs},$$

where M is the multiplier given by

$$M = \frac{\text{hypotenuse of given shadow}}{\text{hypotenuse of given shadow} - \text{hypotenuse of midday shadow}}.$$

[1] Cf. KK, iii. 10 (a-b)

[2] Same rule occurs in RāMr, iii. 23-24; SiSaṃ, iii. 14-15; GGB, iv. 10 (c-d). For an improved version of this rule, see KKM, iii. 32-33.

Rationale.

We have shown above (under vss. 6 – 7) that

$$M = \frac{(\text{day-length} - 10).9}{N^2} + \frac{\text{day-length} - 10}{1000}$$

Therefore,

$$N^2 = \frac{9\,(\text{day-length} - 10)}{M - \dfrac{\text{day-length} - 10}{100}},$$

giving

$$\text{Natakāla } N = \sqrt{\left[\frac{9\,(\text{day-length} - 10)}{M - \dfrac{\text{day-length} - 10}{100}}\right]} \text{ nāḍīs.}$$

Chapter VI

CONJUNCTION OF TWO PLANETS, ECLIPSES, AND THEIR GRAPHICAL REPRESENTATION

CRITERION FOR CONJUNCTION PASSED OR TO COME

1. When the difference between the longitudes 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 the near future); in the contrary case, (it should be understood that) the conjunction has already occurred (in the near past).[1] (31)

This criterion relates to the case when the two planets are in direct motion.

When the two planets are in retrograde motion and the slower one has greater longitude, it should be undersstood 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 direct, it should be understood that the conjunction is to occur; if the planet with lesser longitude is retrograde and the other direct, it should be understood that the conjunction has already occurred.

By the conjunction of two planets is meant the equality of their nirayaṇa (sidereal) longitudes.

DAYS PASSED SINCE CONJUNCTION OR TO PASS BEFORE CONJUNCTION. EQUALISATION OF LONGITUDES.

2. By the sum of their daily motions if they are moving in the opposite directions, or by the difference of their daily motions 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, equalise the longitudes of the two planets.[2] (32)

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 motions when one planet is direct and the other retrograde, and then adding or subtracting, 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 subtracted from the

[1]Same as KA, iii. 2 (c-d)-3 (a-b).

[2]Same as KA, iii. 3 (c-d)- 3½.

longitudes of 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 planetss 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 the case of the retrograde planet and as stated in the case of the direct one."[1]

Sūryadeva Yajvā 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 viz. "When the difference between the longitudes of the two planets is small etc. (vss. 1-2 of the text)" should 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."[2]

DIAMETERS OF THE SUN AND MOON

3. 7400 divided by the Sun's divisor (cheda) 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). (33)

That is,

$$\text{Sun's diameter} = \frac{7400}{\text{Sun's divisor}} \text{ mins.}$$

$$= \frac{7400}{224^\circ + 8^\circ 8' \cos\phi/2} \text{ mins.},$$

where ϕ is the Sun's bhuja.

$$\text{Moon's diameter} = \frac{3100}{\text{Moon's divisor}} \text{ mins.}$$

$$= \frac{3100}{97^\circ + 8^\circ 8' \cos\phi/2} \text{ mins.}$$

where ϕ is the Moon's bhuja.

[1]SiŚe, xi. 12, 14.
[2]From Sūryadeva Yajvā's com.

Examples.

1. When kendra = 0, bhuja = 0 and koṭi = 90°, we have

$$\text{Sun's diameter} = \frac{7400}{224° + 4°4'} \text{ mins.}$$

$$= 32'\ 27''.$$

$$\text{Moon's diameter} = \frac{3100}{97° + 4°4'} \text{ mins.}$$

$$= 30'\ 40''.$$

2. When kendra = 90°, bhuja = − 90° and koṭi = 0, we have

$$\text{Sun's diameter} = \frac{7400}{224} \text{ mins.}$$

$$= 33'2''.$$

$$\text{Moon's diameter} = \frac{3100}{97} \text{ mins.}$$

$$= 32'.$$

3. When kendra = 180°, bhuja = 0 and koṭi = − 90°, we have

$$\text{Sun's diameter} = \frac{7400}{224° - 4°4'}, \text{ mins.}$$

$$= 33'40''.$$

$$\text{Moon's diameter} = \frac{3100}{97° - 4°4'} \text{ mins.}$$

$$= 33'21''.$$

Rationale. The following seems to be the rationale of the above rules.

Since (according to Āryabhaṭa I),

Sun's linear diameter = 4410 yojanas

and Sun's mean distance = 459585 yojanas,

therefore

$$\text{Sun's mean diameter} = \frac{4410 \times 3438}{459585} \text{ mins.}$$

$$= \frac{7390}{224} \text{ or } \frac{7400}{224} \text{ mins. approx.}$$

$$= \frac{7400}{\text{Sun's (mean) divisor}} \text{ mins.}$$

$$\therefore \text{Sun's true diameter} = \frac{7400}{\text{Sun's (true) divisor}} \text{ mins.}$$

Similarly, since (according to Lalla),

Moon's linear diameter = 320 yojanas

and Moon's mean distance = 34377 yojanas,

therefore,

$$\text{Moon's mean diameter} = \frac{320 \times 3438}{34377} \text{ mins.}$$

$$= \frac{3104}{97} \text{ or } \frac{3100}{97} \text{ mins. approx.}$$

$$= \frac{3100}{\text{Moon's (mean) divisor}} \text{ mins.}$$

$$\therefore \text{Moon's true diameter} = \frac{3100}{\text{Moon's (true) divisor}} \text{ mins.}$$

Note. The (manda) divisors of the planets have been stated above in vs. 3, ch. II.

DIAMETER OF SHADOW

4. 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. (34)

The shadow planet (or what is generally known as 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,

$$\text{Diameter of Shadow} = \frac{8300}{\text{Moon's divisor}} \text{ mins.}$$

$$= \frac{8300}{97° + 8°8' \cos\phi/2}$$

where ϕ is the Moon's bhuja.

Rationale. The rationale of this rule is similar to that of the previous one. Adopting the parameters given by Āryabhaṭa I, we have

$$\text{length of Earth's shadow} = \frac{\text{Sun's distance} \times \text{Earth's diameter}}{\text{Sun's diameter} - \text{Earth's diameter}}$$

$$= \frac{459585 \times 1050}{4410 - 1050}$$

$$= \frac{459585 \times 1050}{3360} \text{ yojanas,}$$

and likewise

Diameter of Shadow

$$= \frac{\text{Earth's diameter} \times (\text{length of Earth's shadow} - \text{Moon's distance})}{\text{length of Earth's shadow}}$$

$$= \frac{459585 \times 1050 - 34377 \times 3360}{459585}$$

$$= \frac{367057530}{459585}$$

$$= 798{\cdot}6 \text{ or } 800 \text{ yojanas (approx.)}$$

$= \frac{7760}{97}$ mins., for 10 yojanas = 1 min.

$= \frac{7760}{\text{Moon's divisor}}$ 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

$$\text{Diameter of Shadow} = \frac{8300}{\text{Moon's divisor}} \text{ mins. (approx.)}$$

The commentator Sūryadeva Yajvā thinks that Mañjula has taken 850½ yojanas as the linear measure of the diameter of Shadow.

DIAMETERS OF THE PLANETS

5. 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 and 10. (35)

That is,

$$\text{Diameter of Mars} = \frac{6 \times 10}{D + 10} \text{ mins.}$$

$$\text{Diameter of Mercury} = \frac{11 \times 10}{D + 10} \text{ mins.}$$

$$\text{Diameter of Jupiter} = \frac{20 \times 10}{D + 10} \text{ mins.}$$

$$\text{Diameter of Venus} = \frac{12 \times 10}{D + 10} \text{ mins.}$$

$$\text{Diameter of Saturn} = \frac{22 \times 10}{D + 10} \text{ mins.,}$$

where D stands for the śīghra divisor of the planet concerned.

For the śīghra divisors of the planet Mars etc., see supra, ch. III, vss. 5 and 6. The above 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 I and Mañjula for three positions, viz. (1) when the planets are at their śīghroccas, (2) when they are at their mean distances, and (3) when they are at their śīghranīcas. The results obtained are as shown in the following table.

		True diameter according to Āryabhaṭa I	*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)	24′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 the actual ones as will be evident from their mean values given by modern astronomers:

	Mean diameter
Mars	14·3
Mercury	9″
Jupiter	41″
Venus	39″
Saturn	17″

The distances and diameters of the planets stated in Hindu works on astronomy are incorrect as they are based on Āryabhaṭa I's wrong hypothesis that all planets have equal linear motion.

LATITUDES OF MOON ETC.

6-7. Subtract the longitude of the planet's ascending node from the true-mean longitude of the planet (in the case of Mars, Jupiter, and Saturn) and from the longitude of the planet's Śīghrocca (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. multiplied 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.[1] (36-37)

That is, the celestial latitudes of the Moon etc. are obtained in terms of minutes by applying the following formulae:

(1) Moon's latitude $= 8°8' \sin(\text{Moon} - A) \times 36$

(2) Mars' latitud $= \dfrac{8°8' \sin(\text{true-mean planet} - A) \times 12 \times V}{D}$

(3) Jupiter's latittudes $= \dfrac{8°8' \sin(\text{true-mean planet} - A) \times 9 \times V}{D}$

(4) Saturn's latitude $= \dfrac{8°8' \sin(\text{true-mean planet} - A) \times 16 \times V}{D}$

(5) Mercury's latitude $= \dfrac{8°8' \sin(S' - A) \times 16 \times V}{D}$

(6) Venus' latitude $= \dfrac{8°8' \sin(S' - A) \times 16 \times V}{D}$

where V = planet's corrected vyāsa
D = planet's sīghra divisor
A = planet's ascending node
and S′ = planet's śīghrocca 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, gives the longitudinal distance of the planet 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″ × 36 = 292′ 48″
Mars	8′8″ × 12 or 97′36″

[1]Cf. KA, iv. 1-2½.

Mercury	8′8″ × 16 or 130′8″
Jupiter	8′8″ × 9 or 73′12″
Venus	8′8″ × 16 or 130′8″
Saturn	8′8″ × 16 or 130′8″

Those given by Āryabhaṭa I and Brahmagupta are:

Planet	Greatest celestial latitude according to	
	Āryabhaṭa I	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 I by about 8·5 percent in the case of Moon, Mars, Mercury, Venus and Saturn but by 22 per cent 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.

DISTANCE BETWEEN TWO PLANETS IN LONGITUDINAL CONJUNCTION AND CRITERION FOR PLANETARY OCCULTATION (BHEDA)

8. Take the difference or sum of the latitudes of the two planets (in longitudinal conjunction) according as they 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 occultation (bheda) (of the upper planet by the lower one). (38)

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 (channa). See Rājamṛgāṅka, viii. 13 (a-b).

The commentator Praśastidhara interpolates here the following verse:

Saumyakṣepo'dhiko jetā hīnakṣepaśca dakṣiṇe |
Ubhayorekamārgaśced bhinnamārge jayottaraḥ ||

i.e., "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 northernn one is the victor."

The Sūrya-siddhānta[1] 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)."

Puliśācārya[2] combines the two statements: "(In the 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."

LAMBANA OR PARALLAX IN LONGITUDE

9. In the 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 the computation of lambana). Calculate the hour angle (by subtracting it from half the duration of the planet's day or vice versa). Diminish 20 by the hour angle (in terms of ghaṭīs etc.). then multiply by the hour angle, and divide by twice the palakarṇa ("hypotenuse of the equinoctial midday shadow") (in terms of aṅgulas and vyaṅgulas): the result is the lambana (in terms of ghaṭīs).[3] (39)

That is,

$$\text{lambana} = \frac{(20-h)h}{2.\ \text{palakarṇa}} \text{ ghaṭīs},$$

h being the hour angle (in terms of ghaṭīs).

Explanation.

Let

$$\text{lagna} - \text{planet} = x \text{ signs, say.}$$

This is grahonalagna. The corresponding time of rising

$$= \frac{60.x}{12} \text{ ghaṭīs}$$

$$= 5x \text{ ghaṭīs.}$$

This is grahonalagnamakṣaghnam and denotes lambanadyugata.

The corresponding hour angle

= half the duration of the planet's day — 5x ghaṭīs
= h ghaṭīs, say.

[1] vii. 23 (a-b).

[2] See KK, viii. opening lines of Bhaṭṭotpala's com.

[3] Same rule occurs in RāMṛ, vii. 4-6, also see viii. 13 (c-d)-15 (a-b); GaĀ, iv. 14-15; Mallaya Yajvā's SiSā, vi. 1-3 (a-b); SiSam, iv. 9-10 (a-b).

Then, according to the rule,

$$\text{lambana} = \frac{(20-h)\,h}{2.\ \text{palakarṇa}}\ \text{ghaṭīs}.$$

This formula is empirical. The commentator Sūryadeva Yajvā has suggested the following rationale.

Sūryadeva Yajvā's Rationale

Case 1. When $\theta = 0$.

Sūryadeva Yajvā has shown that in this case the lambana has its maximum value = 48′30″ or roughly 50′, when h = 10 ghaṭīs. At that time

$$(20-h)\,h = 100.$$

So applying the proporation: "When (20-h) h = 100, lambana amounts to 50′, what will it amount to when (20-h) h has its own value ?" The result is

$$\text{lambana} = \frac{50\,(20-h)h}{100}\ \text{mins.}$$

$$= \frac{(20-h)\,h}{2}\ \text{mins.}$$

$$= \frac{(20-h)\,h}{2.12}\ \text{ghaṭīs}$$

(because 12 lambanakalaās = 1 gaṭī)

$$= \frac{(20-h)\,h}{2.\ \text{palakarṇa}}\ \text{ghaṭīs},$$

because when $\phi = 0$, palakarṇa = 12.

Case 2. When $\phi = 0$.

In this case the equator is inclined to the horizon at an angle equal to $(90-\phi)$ degrees. So in this case

$$\text{lambana} = \frac{(20-h)\,h.\ \cos\phi}{2.12}$$

$$= \frac{(20-h)\,h}{2.\ \text{palakarṇa}}\ \text{ghaṭīs}.$$

It is noteworthy that the astronomer Lalla who flourished anterior to Mañjula also gave the same rule for lambana, for Sūryadeva Yajvā ascribes the following half-verse to Lalla:

Natonanighnā khayamā vibhaktā
dvighnākṣakarṇena vilambanāḍyaḥ ।

i.e.,

$$\text{lambana in nāḍīs} = \frac{(20 - h)\, h.}{2.\ \text{palakarṇa}}$$

Observation. The above rule is only approximate. For, at the equator when the Sun is at the central ecliptic point (vitribhalagna), it correctly yields lambana = 0, but when the Sun is on the horizon it gives lambana = 3⅛ ghaṭīs, the correct value being 4 ghaṭīs in this case.

Text of verse 9.

The text occurring in the commentary of Praśastidhara runs as follows:

Grahonalagnamakṣaghnaṃ lambanadyugataṃ yutau ।
(Bhāgādi dviguṇaṃ kāryaṃ lambanadyugataṃ bhavet ॥
Lambanadyugatāt pañcadaśabhirnatasādhanam ।
Lambanaṃ dvyakṣakarṇāptaṃ natonāhatavimśateḥ ॥

The second and third lines (which have been interpolated by some one) are meant to supply the link between the first and fourth lines. The whole text when translated will run as follows:

"In the case of yuti, (occultation or eclipse), subtract 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 subtracting it from 15 ghaṭīs.[1]] Twenty diminished and then multiplied by that nata, and the result (obtained) divided by twice the akṣakarṇa (or palakarṇa) gives the lambana (in terms of nāḍīs)"[2].

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

[1] 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 in place of half the duration of the planet's day." He further says: "Those who have explained the term dinārdha as meaning "half the duration of the planet' calculated with the help of cara or twice the ascensional difference" are wrong, because there is lambana at the dṛkṣepalagna also."

[2] Cf., RāMr, vii. 4-6.

the rules stated in the (Laghu) mānasa being in agreement with the actual value, all astronomers compute the planets according to the rules stated in the (Laghu) mānasa."[1]

KHĀRKA OR MADHYALAGNA

10. 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 subtract (signs equal to) one-fifth of the (corresponding) nata-ghaṭīs from the longitude of the Sun; in the contrary case (i.e., in the western hemisphere), add the same: the result is the longitude of the Khārka (i.e., the madhyalagna or the meridian ecliptic point).[2] (40)

It is assumed here 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 (vitriba 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, subtract 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 to 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 cara, obtain the nataghaṭīs. Dividing these nataghaṭīs by 5, take the quotient as signs, and multiplying the remainder by 30 and dividing by 5, take the quotient as degrees. Then multiplying the remainder of that by 60 and dividing by 5, take the quotient as minutes. Subtract 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."

NATI OR PARALLAX IN LATITUDE

11. Find the product of the cara (vināḍīs) (obtained from the tropical longitude of that Khārka) and 6 and divide by the palabhā, and apply it to 50 diminished and

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[1]Quoted from Yallaya's com. on SūSi, v. 3-9.

[2]Same rule occurs in RāMṛ, vii. 7-10; GaA, iv. 16-17 (a-b); Mallaya Yajvā's SiSā, vi. 3 (c-d)-4; SiSaṁ, iv. 10 (c-d)-11.

multiplied by the palabhā (as a subtractive 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).[1] (41)

That is,

$$\text{nati} = \frac{2}{25}\left[(50-\text{palabhā})\ \text{palabhā} \pm \frac{\text{caravināḍīs} \times 6}{\text{palabhā}}\right] \text{mins.},$$

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

Rationale.

This rule is based on the following two lemmas.

Lemma 1. The latitude $\phi = \dfrac{(50-\text{palabhā}).\ \text{palabhā}}{10}$ degrees.

The commentator Sūryadeva Yajvā says: "Here it is assumed that the latitude ϕ = (50 − palabhā). palabhā vināḍīs", so that

$$\phi = \frac{(50-\text{palabhā}).\ \text{palabhā}}{10} \text{ degrees.}$$

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

Verification.

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

When palabhā = 5 aṅgulas, $\phi = 22° 30'$, which is approximately true at Ujjain. It may be mentioned that, according to Āryabhaṭa 1, the latitude of Ujjain = 22°30′.

Lemma 2.

The declination $\delta = \dfrac{36.\text{caravināḍīs}}{\text{palabha}}$ mins.

Sūryadeva Yajvā says that

$$\text{caravināḍīs} = \frac{\delta.\ \text{palabhā.}}{12\text{x}3}$$

[1]Same rule occurs in RāMṛ, vii. 11-13 (a-b); Mallya Yajvā's SiSā, vi. 5-7; SiSaṃ, iv. 11a-14 (a-b).

Rationale. We have

$$\text{caravināḍīs} = \frac{2R\tan\delta\tan\phi}{6} \text{ approx.}$$
$$= \frac{R\tan\delta \times 12\tan\phi}{12 \times 3}$$
$$= \frac{\delta \times \text{palabhā}}{36} \text{ approx.,}$$

δ being in terms of minutes.
Therefore,

$$\delta = \frac{36.\text{caravināḍīs}}{\text{palabhā}} \text{ mins. (approx.)}$$

Using these two lemmas, Mañjula's rule may be established as follows:

Using these two lemmas, Mañjula's rule may be established as follows:

$$\text{Nati} = 48'30'' \sin(\phi \mp \delta)$$
$$= 48'.5 \left[\frac{\phi}{R} \mp \frac{\delta}{R}\right] \text{ approx.}$$
$$= 48'.5 \left[\frac{\phi}{57.3} \mp \frac{\delta}{R}\right]$$
$$= 48'.5 \left[\frac{(50 - \text{palabhā})\,\text{palabhā}}{57{\cdot}3 \times 10} \mp \frac{\text{caravināḍīs}.36}{R.\ \text{palabhā}}\right]$$

where δ being in minutes, R is also in minutes equal to 3438′.

$$= \frac{48'{\cdot}5}{573} \left[(50 - \text{palabhā})\,\text{palabhā} \mp \frac{6.\ \text{caravināḍīs}}{\text{palabhā}}\right],$$

because 6/R = 6/3438 = 1/573.

$$= \frac{2}{25}\left[(50 - \text{palabhā})\,\text{palabhā} \mp \frac{6.\ \text{caravināḍīs}}{\text{palabha}}\right].$$

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

Tanmadhyalagnotthacarādrasaghnāt
palaprabhāptena ca saṃskṛtācca |
Palaprabhonāhatapūrṇabāṇād
dvighnāttathā tattvahṛtānnatiḥ syāt ||

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 the Rāja-mṛgāṅka (vii. 13c-d).

NATI CORRECTION

12. 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.[1]

In the case of eclipse or occultation, the lower planet is evidently the eclipser (of the upper one). (42)

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.

STHITYARDHA OR SEMI-DURATIONS

13. Subtract 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-different of the two bodies, if they are moving in like directions: the result is the sthityardha (in terms of ghaṭīs)[2]. (43)

14. 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 the even nodal quadrant; otherwise the larger one is the spārśika.[3] (44)

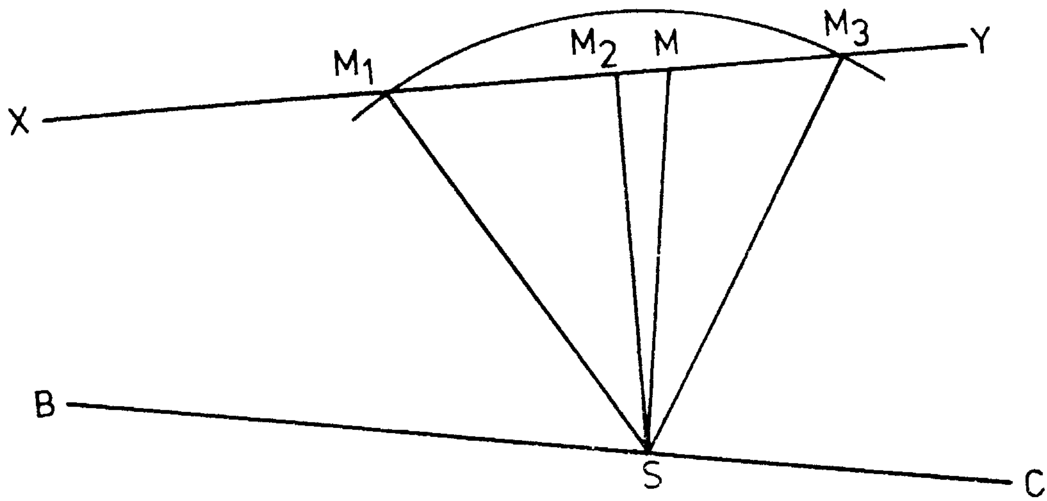
[1] Cf. RāMṛ, vii. 15; GaĀ, iv. 18 (c-d)-19 (a-b); Mallaya Yajvā's SiSā, vi. 8; SiSaṃ, IV. 14. (c-d)-15 (a-b).

[2] Cf. RāMṛ, vii. 17-18, also 23; GaĀ, iv. 21 (c-d)-22 (a-b); KA, iii. 15½-16½; GGB, v. 3 (c-d)-5. In the case of occultation of one planet by another, Rājamṛgānka (vii. 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."

[3] Same rule occurs in RāMṛ, vii. 19-20; GaĀ, iv. 21 (c-d)-22 (a-b); KA, iii. 15½-17½; GGB, v. 6. For similar rules see VSi, V. sec. 5, vss. 5-6; MSi, v. 11-12; KKu, iv. 11-12. KU, iv. 10.

The above rule is meant to find the sparśika and maukṣika sthityardhas without using the process of iteration (asakṛtkarma).

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_3 is the position of the Moon's centre at the end of the lunar eclipse, M_3S = sum of the semi-diameters of the Moon and Shadow. M_2 is the 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

$$M_1M_2 = M_2M_3 = \sqrt{\left[(M_1S)^2 - (M_2S)^2\right]} \text{ or } \sqrt{(M_3S)^2 - (M_2S)^2}$$

$$= (\text{sum of semidiameters of Moon and shadow})^2 - (\text{shortest distance between them})^2$$

or, sthityardha = M_1M_2 mins.

$$= \frac{M_1M_2 \times 60}{\text{motion-difference of Sun and Moon}} \text{ ghaṭīs.}$$

Now in the triangle SM_2M, right-angled at M_2, MS is the Moon's latitude for the time of conjunction of M and S and angle $MSM_2 = i$, the inclination of the Moon's orbit to the ecliptic.

Therefore,

$$M_2M = \frac{R\sin i \times MS}{R}$$

$$= \frac{292'\ 48'' \times MS}{3438}, \text{ because according to Mañjula } i = 292'$$

$$= \frac{292'\ 48'' \times MS}{3438}, \times \frac{60}{731} \text{ ghaṭīs}$$

$$= \frac{MS}{144} \text{ ghaṭīs}$$

Therefore,

spārśika sthityardha $= M_1M_2 + M_2M$
= sthityardhaghaṭīs + MS/144 ghaṭīs,

and maukṣika sthityardha $= M_2M_3 - M_2M$
= sthityardhaghaṭīs − MS/144 ghaṭīs.

This is so when the conjunction of the Moon and the Shadow takes place in an odd quadrant, as in the figure.

When the conjunction of the Moon and the Shadow occurs in an even quadrant, MS/144 ghaṭīs are added and subtracted reversely.

TIMES OF CONTACT AND SEPARATION IN A SOLAR ECLIPSE

15. (Severally) decrease and increase the māsāntadyugata (i.e., the day elapsed since sunrise at the end of the lunar month when the Sun and Moon are in conjunction), corrected for lambana, by the (spārśika and maukṣika) sthityardhas: the results are the times of contact and separation in the case of a solar eclipse.[1]

In the case of a lunar eclipse, correction for lambana and nati are not applied. (45)

AKṢAVALANA

16. 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 aṅgulas for a circle of diameter 32 aṅgulas. Its direction is north in the eastern hemisphere and south in the western hemisphere.[2] (46)

[1]Cf. RāMṛ, viii. 25; SiSā, vi. 10; KA, iii. 17½.

[2]Same rule occurs in RāMṛ, vi. 33; GM, vs. 73; GaĀ, iv. 30; GGB, vii. 5 (a-b).

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 circle of radius 16 aṅgulas,

$$\text{akṣavalana} = \frac{\text{palabhā} \times \text{nataghaṭikās}}{12} \text{ aṅgulas},$$

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 $\phi°$, what will be the value of the akṣavalana corresponding to the given nataghaṭikās?" The result is

$$\text{akṣavalana} = \frac{\text{nataghaṭikās} \times \phi}{15} \text{ degrees}$$

$$= \frac{\text{nataghaṭikās} \times \phi \times 60}{15} \text{ mins.}$$

$$\text{Now palabhā} = \frac{5 \text{ aṅgulas} \times \phi°}{24°} \text{ approx.}$$

Therefore,

$$\text{akṣavalana} = \frac{\text{nataghaṭikās} \times (5/24)\phi \times 60}{15.(5/24)} \text{ mins.},$$

in a circle of radius 3438′.

$$= \frac{\text{nataghaṭikās} \times \text{palabhā} \times 60 \times 16}{15.(5/24).\ 3438} \text{ aṅgulas},$$

$$= \frac{\text{nataghaṭikās} \times \text{palabhā}}{12} \text{ aṅgulas},$$

in a circle of radius 16 aṅgulas. 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 on the horizon of the eclipsed body).

AYANAVALANA AND TRUE VALANA

17. The distance, in terms of signs etc., of the nearer solstice from the planet, multiplied by 2, gives the ayanavalana (in terms of aṅgulas).

The true valana is the sum or difference of the two (valanas, ākṣa and āyana), (according as they are of like or unlike directions).[1] (47)

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

$$\text{ayanavalana} = 2d \text{ aṅgulas},$$

where d is the distance of the nearer solstice from the eclipsed planet.

Rationale.

Suppose that the eclipsed planet is at the 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.

$$\text{Rsin (ayanavalana)} = \text{Rsin } 24° \text{ or } 1397 \text{ mins.}$$

Therefore in the circle centred at the eclipsed planet and radius equal to 16 angulas,

$$\text{Rsin (ayanavalana)} = \frac{1397 \times 16}{3438}$$

$$= 6 \text{ aṅgulas.}$$

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 aṅgulas, so that when the distance of the nearer solstice from the eclipsed planet is d signs, the ayanavalana is equal to 2d aṅgulas. Hence the rule.

Direction of the ayanavalana

When the 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 valana is the deflection of the east point of the ecliptic from the east point of the prime vertical on the horizon of the eclipsed body.

AṄGULA-DEGREE RELATION

18(a-b). At the end of the Yaṣṭi (radius) of 56 aṅgulas from the centre of the directions (diṅmadhya), one aṅgula is equal to one degree. (48ab).

The value of a radian has been assumed here as equal to 56°. The correct value is 57°17′45″.

What is meant by the above rule is that if a circle is drawn with radius equal to 56 aṅgulas, the circumference will contain 360 aṅgulas approx. Then 1° of the circumference of the circle will be equal to 1 aṅgula.

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 aṅgulas in length, attach at its end, at right angles to it, a scale graduated with the marks of aṅgulas. 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 aṅgulas are there between the planets, so many degrees lie between them."

PARILEKHA OR DIAGRAM OF ECLIPSE

18(c-d). On the circumference of the circle of the directions there is a Prācī ("east-west line"). At the end of the valana there is another (east-west line) which is different from that. (48cd)

19. From that (latter) 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. (49)

What is meant is this: "Construct a circle of radius 16 aṅgulas, 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 (valanāgraprācī). 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 the case of a 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 eclipsing 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."

20. 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 Parilekha (i.e., exhibit the iṣṭagrāsa) by making use of the distance between the two planets. (50)

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 the valana and (2) the path of the Moon as centre, and the Moon's semi-diameter, in terms of aṅgulas, as radius, draw a circle (denoting the Moon's disc). Next taking the centre of the circle of radius 16 aṅgulas itself as centre, and the Sun's semi-diameter, in terms of aṅgulas, 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 the 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 aṅgulas, the valana for 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.

Chapter VII
RISING AND SETTING OF HEAVENLY BODIES

AKṢADṚKKARMA OR VISIBILITY CORRECTION DUE TO LOCAL LATITUDE

1. Multiply the cara-correction (see vs. 5 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 subtracted 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).[1] In the case of setting (the cara-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 subtracted when the planet's latitude is positive). (51)

That is,

$$\text{akṣadṛkkarma} = \frac{\text{cara-correction} \times 15}{\text{vināḍīs of oblique ascension of rising sign}} \text{ degrees}$$

Rationale.

From vs. 5 below, we have

$$\text{cara-correction} = \frac{\text{planet's latitude} \times \text{palabhā}}{36 - (\text{planet's cara})/49} \text{ vināḍīs.} \qquad (1)$$

The present rule tells us how 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 will rise during half the viṇāḍīs given by (1)?" The result is

$$\frac{30 \times (\text{cara correction, in vināḍīs})/2}{\text{vināḍīs of oblique ascension of the rising sign}} \text{ degrees}$$

$$= \frac{15 \times (\text{cara correction, in vināḍīs})}{\text{vināḍīs of oblique ascension of the rising sign}} \text{ degrees.}$$

Hence the rule.

---

[1] Vide supra, vi. 7.

AYANA-DṚKKARMA OR VISIBILITY CORRECTION DUE TO PLANET'S AYANA

2. Multiply one-fourth of the planet's latitude by the Rversed sine of the planet's koṭi[1] 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 subtracted 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.) (52)

That is,

$$\text{ayana-dṛkkarma} = \frac{\text{Rvers (planet's koṭi)} \times \text{(planet's latitude)/4}}{\text{vināḍīs of oblique ascension of the rising sign}} \text{ degrees.}$$

Rationale

Let β denote the planet's latitude and V the vināḍīs of the oblique ascension of the rising sign. Then[2]

$$\text{ayana-dṛkkarma} = \frac{\text{Rvers (planet's koṭi)} \,.\, \beta \,.\, \text{Rsin}24^\circ}{R^2 \times 6} \times \frac{30}{V} \text{ degrees}$$

$$= \frac{8^\circ 8' \text{ vers (planet's koṭi)} \,.\, \beta \,.\, 8^\circ 8' \sin 24^\circ \,.\, 30}{(8^\circ 8')^2 \,.\, 6 \,.\, V}$$

$$= \frac{8^\circ 8' \text{ vers (planet's koṭi)} \,.\, \beta}{\frac{(8^\circ 8')^2 \,.\, 6}{3^\circ 15' \,.\, 30} V}, \text{ because } 8^\circ 8' \sin 24^\circ = 3^\circ 15'$$

$$= \frac{8^\circ 8' \text{ vers (planet's koṭi)} \,.\, \beta}{(66^\circ 5'/16^\circ 15') \,.\, V}$$

$$= \frac{8^\circ 8' \text{ vers (planet's koṭi)} \,.\, \beta}{4V}$$

$$= \frac{8^\circ 8' \text{ vers (planet's koṭi)} \,.\, \beta/4}{V} \text{ degrees.}$$

[1] Planet's koṭi is the koṭi of the planet's longitude. See supra, ch. III, vss. 1-2.

[2] See Ā, iv. 36.

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 its setting one gets the planet's astalagna (i.e., the longitude of that point of the ecliptic that sets with the planet).

UDAYĀRKA AND ASTĀRKA FOR MOON ETC.

3. 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 subtract them from the true longitude of the planet: the results are called the Udayārka and the Astārka of the Moon etc. (53)

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

$$= \frac{30 \times T}{V},$$

where T = time-degrees in vināḍīs
= time-degrees × 10
and V = vināḍīs of the oblique ascension of the sign occupied by the planet.

DṚKKARMA OR VISIBILITY CORRECTION
(Alternative Method)

3′. 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 heliacal setting. (53′)

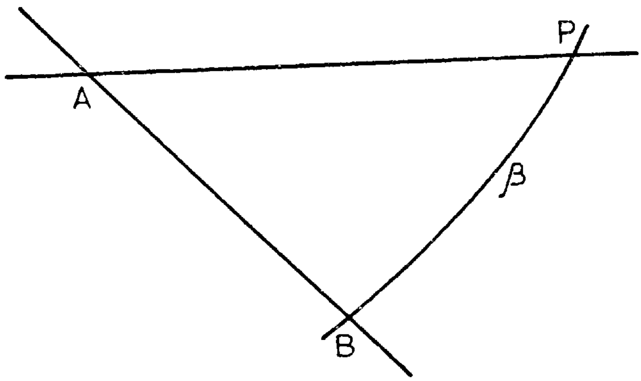
That is,

$$\text{visibility correction} = \frac{\beta \times v}{900} \text{ degrees},$$

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

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 the arc AB the planet's visibility correction (both measured in minutes of arc). Since the angle APB is very small, treating the spherical triangle ABP, right-angled at B, as a plane triangle, we have



arc AB $= \beta \tan (\text{angle APB})$

$$= \frac{\beta \cdot (\text{valana in minutes})}{R} \text{ mins. approx., } R = \text{radian in minutes}$$

$$= \frac{\beta \cdot (\text{valana in mins.})}{60 \cdot R} \text{ degrees}$$

$$= \frac{\beta}{60 \cdot R} \cdot \frac{(\text{valana in aṅgulas}) \cdot R}{16} \text{ degrees,}$$

because valana in aṅgulas corresponds to a circle of radius 16 aṅgulas

$$= \frac{\beta \times (\text{valana in aṅgulas})}{960} \text{ degrees}$$

$$= \frac{\beta \cdot v}{900} \text{ degrees approx.}$$

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

ASTĀRKA AND UDAYĀRKA FOR CANOPUS (AGASTYA)

4. The degrees of Astārka and Udayārka for the star Canopus (Agastya) are 77 and 97, respectively diminished and increased by 8 times the equinoctial midday shadow at the local place.[1] (54)

That is,

Udayārka for Canopus = 97 + 8P degrees
and Astārka for Canopus = 77 − 8P degrees,

where P denotes the equinoctial midday shadow, in terms of aṅgulas.

Rationale.

In the case of Canopus

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

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

The commentator Sūryadeva Yajvā has shown that

Polar longitude of Canopus = 87°
akṣadṛkkarma for Canopus = 8P approx.

and time-degrees for heliacal rising or setting of Canopus = 10°.

Hence the rule.

CARA CORRECTION

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

That is,

$$\text{true cara} = \text{cara} \pm \frac{\text{planet's latitude} \times \text{palabhā}}{36 \sim (\text{planet's cara})/49}$$

where cara stands as usual for twice the planet's ascensional difference in terms of vināḍīs, + or − sign being taken according as

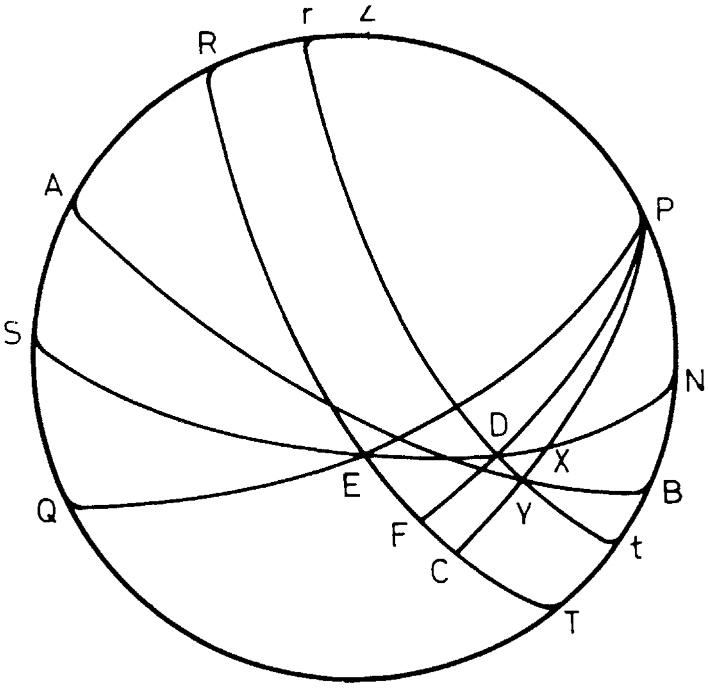
[1] For similar rules see VSi, ch. VIII, sec. 2, vss. 23-24; KKu, vi. 15; GL, ix. 22.

cara and cara-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 time of its rising on the horizon. PXC is the planet's hour circle (dhruvaprotavṛtta) and Y and 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 = $90° - \phi$, and arc XY = planet's latitude β (approx.), so that arc DY = $\beta \tan \phi$.

Now mean cara = 2EF approx. and true cara = 2EC. Therefore, cara correction = 2EC − 2EF = 2FC.

$$\text{Now DY} = \text{XY} \tan \phi$$
$$= \beta \tan \phi$$
$$= \frac{\beta \times \text{palabhā}}{12}.$$

$$\therefore 2FC = 2 \cdot \frac{\beta \times \text{palabhā}}{12} \times \frac{R}{R\cos\delta}$$

$$= \frac{2 \cdot \beta \cdot \text{palabhā}}{12 \cdot R\cos\delta/R} \text{asus or mins.}$$

$$= \frac{2 \cdot \beta \times \text{palabhā}}{72 \cdot R\cos\delta/R} \text{ vināḍīs}$$

$$= \frac{\beta \cdot \text{palabhā}}{36 \cdot R\cos\delta/R} \text{ vināḍīs.}$$

This is the correct formula for the cara correction as shown by the commentator Sūryadeva Yajvā. Mañjula has replaced the denominator 36 . Rcosδ/R by 36 ~ (planet's cara)/49 empirically.

The rationale given by N.K. Majumdar is incorrect.

Chapter VIII
VYATĪPĀTA AND VAIDHṚTA

DURATION OF VYATĪPĀTA AND VAIDHṚTA

1. 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 aṅgulas of) the equinoctial 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 aṅgulas of) the equinoctial midday shadow.[1] (56)

The phenomenon of Vyatīpāta (also called Cakrārdha Vyatīpāta or Lāṭa Vyatīpāta) is said to occur when the Sun and Moon are in the same Gola ("hemisphere, northern or southern") but in different ayanas[2] 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 then 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 the same is called the middle of Vyatīpāta. Sometime prior to this the difference between the declinations of the Sun and Moon happens to be equal to the sum of the semi-diameters of the Sun and Moon: Vyatīpāta is then said to begin. Sometime later than that the difference between the declinations of the Sun and Moon again happens to be equal to the sum of the 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 Golas ("hemispheres, 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 happen to be numerically the same is called the middle of Vaidhṛta. Sometime prior to this the difference between the numerical values of their declinations happens to be equal to the sum of their semi-diameters; Vaidhṛta is then said to begin. Sometime later than that the difference of the numerical values 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. It may be derived as follows:

In the case of Vyatīpāta, the Sun and Moon being in the same Gola,

[1]Same as KA, ii. 24-24½.

[2]The northern ayana is the period from winter solstice to summer solstice and southern ayana, from summer solstice to winter solstice.

Sun's day-length = 30 nāḍīs ± Sun's caravināḍīs
and Moon's day-length = 30 nāḍīs ± Moon's caravināḍīs.

Therefore,

Sun's day-length ~ Moon's day-length = Sun's caravināḍīs
~ Moon's caravināḍīs. (1)

At the time of the middle of Vyatīpāta,

Sun's declination = Moon's declination,

so that

Sun's caravināḍīs = Moon's caravināḍīs.

Therefore from (1), at the time of the middle of Vyatīpāta

Sun's day-length ~ Moon's day-length = 0.

At the time of beginning or end 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 caravināḍīs

$$= 2 \times 32 \tan \phi \times 1/6 \text{ (roughly)}$$

$$= 2 \times 32 \times \frac{\text{palabhā}}{12} \times \frac{1}{6}$$

= palabhā (in aṅgulas), approx.

Therefore, at the beginning or end of Vyatīpāta,

Sun's day-length (in vināḍīs) ~ Moon's day-length (in vināḍīs)
= palabhā (in aṅgulas).

Hence it follows that Vyatīpāta continues until

Sun's day-length ~ Moon's day-length (in vināḍīs)
< palabhā (in aṅgulas).

In the case of Vaidhṛta, the Sun and Moon being in different Golas,

Sun's day-length (night-length) = 30 nāḍīs ± Sun's caravināḍīs

and

Moon's night-length (day-length) = 30 nāḍīs ± Moon's caravināḍīs.

Therefore,

Sun's day-length (night-length) ~ Moon's night-length (day-length)
= Sun's caravināḍīs ~ Moon's caravināḍīs.

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 aṅgulas).

Chapter IX
ELEVATION OF MOON'S HORNS

MOON'S SHADOW

1. **From the instantaneous longitude of the Moon corrected for the two visibility corrections (akṣadṛkkarma and ayanadṛkkarma) 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 the Moon's day deduce the gnomonic shadow due to moon-light, as in the case of the Sun.** (57)

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 ascensions of the intervening signs.

(2) **Then find the Moon's true cara by using the rule stated in vs. 55 (vs. 5 of ch. VII)**

(3) **By using the Moon's** true cara find the length of the Moon's day.

(4) Using that find the Moon's meridian shadow in the manner described in vs. 26 (vs. 5 of ch. III).

(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 vss.** 27-28 (vss. 7-8 of ch. III).

The shadow due to a planet is also obtained similarly.

SITA AND ASITA

2 (a-b). **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.** (58ab)

That is, in the light fortnight,

sita = (K − 2) (1 + 1/7) aṅgulas,

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) aṅgulas,

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°) 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°) amount to 168° the measure of the sita is 32 aṅgulas, what will be the measure of the sita when (M − S − 12°) has the given value?" The result is:

$$\text{sita} = \frac{(M - S - 12) \times 32}{168} \text{ aṅgulas}$$

$$= \left(\frac{M - S}{6} - 2\right)(1 + 1/7) \text{ aṅgulas}$$

$$= (K - 2)(1 + 1/7) \text{ aṅgulas,}$$

where K denotes the number 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°) − 12° amounts to 168 degrees the asita amounts to 32 aṅgulas, what will be the measure of the asita when M − (S + 180°) − 12° has the given value?" The result is:

$$\text{asita} = \frac{[M - (S + 180°) - 12°] \times 32}{168}$$

$$= \left[\frac{M - (S + 180)}{6} - 2\right](1 + 1/7)$$

$$= (K - 2)(1 + 1/7) \text{ aṅgulas,}$$

where K denotes the number of karaṇas elapsed since the beginning of the dark fortnight. Hence the rule.

TRUE VALANA

2(c-d). The valana (obtained in vs. 17 of ch. VII) 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. (58cd)

That is,

$$\text{true valana} = \text{valana} \pm \frac{\text{Moon's latitude}}{180},$$

+ 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 aṅgulas. Let β mins. be the Moon's latitude. Then the Moon's latitude for the circle of radius 16 aṅgulas

$$= \frac{\beta \times 16}{R} \text{ aṅgulas}$$

$$= \frac{\beta}{215} \text{ aṅgulas.}$$

Hence

$$\text{true valana} = \text{valana} \pm \frac{\beta}{215} \text{ aṅgulas.}$$

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

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

Vikṣepatithidasrā(215)ṃśasaṃskṛtaṃ valanaṃ sphuṭam ||

In the diagram exhibiting the elevation of the Moon's horns, the true valana 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).

CHEDA OR RADIUS OF INNER ARC OF SITA

2′. The difference of 15 and the number of karaṇas (lit. 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 cheda.[1] This should be laid off from the (inner) extremity of the sita (śukla) towards the interior of the Moon's circle. (58′)

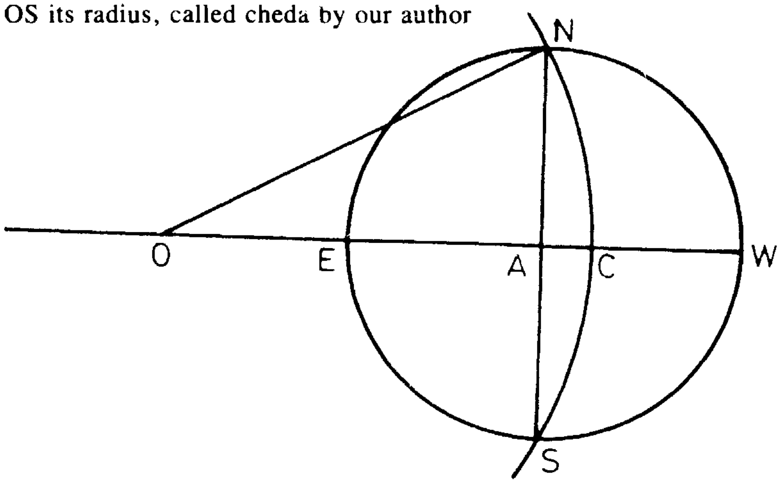
That is,

$$\text{cheda} = \frac{1}{2}\left[(15 - K) + \frac{16^2}{(15 - K)}\right]$$

where K is the number of karaṇas elapsed since the beginning of the current fortnight.

The cheda defined above 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 an 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 cheda by our author



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

$$NA = 16 \text{ aṅgulas}$$

$$OA = \frac{1}{2}\left[\frac{16^2}{x} - x\right] \text{aṅgulas}$$

$$ON = \frac{1}{2}\left[\frac{16^2}{x} + x\right] \text{aṅgulas.}$$

[1]The literal translation is: "16^2 divided and increased by the difference between 15 and the number of karaṇas elapsed since the beginning of the (current) fortnight, and then halved gives the cheda."

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

$$\text{cheda ON} = \frac{1}{2}\left[\frac{16^2}{AC} + AC\right] \text{ aṅgulas.} \qquad (1)$$

This is the formula stated by Vaṭeśvara, Śrīpati, and Āryabhaṭa II. See VSi, ch. VII, sec. 1, vs. 26; SiŚe, x. 22; MSi, vii. 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

$$\frac{AW}{15} = \frac{CW}{K} = \frac{AC}{15 - K} = t, \text{ say.}$$

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

$$\text{cheda ON} = \frac{1}{2}\left[\frac{16^2}{15 - K} + (15 - K)\right] \text{ aṅgulas,}$$

which is the form in which Mañjula states the value of the cheda ON.

Since AW = 16 aṅgulas, 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 commentators 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 text in Ms. A_1 containing the text along with the commentary of Praśastidhara but it has not been explained or illustrated in the commentary of Praśastidhara and seems to be an interpolation there. This verse, however, seems to be necessary, because the cheda defined in this verse has been referred to and used in vs. 3 below. It seems to me that Yallaya (or whosoever be the author of this verse), realizing the necessity of a rule giving the value of cheda, has added this verse, and to keep the total number of verses limited to 60 replaced vss. 1 and 2 of ch. VII (giving visibility corrections) by vs. 3′ of the same chapter (giving an alternative method of the same correction).[1]

LAYING OFF OF SITA OR ASITA IN THE DIAGRAM OF THE MOON

3. **In the light fortnight the sita and in the dark fortnight the asita increases from the west point of the Moon's disc towards the east. (What is meant by saying this is:**

[1]Vs. 3′ of ch. VII occurs in Parameśvara's commentary also and must have been composed by an author anterior to him.

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 cheda (defined in vs. 2′ 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 cheda). (59)

CONCLUDING REMARK

4. This book, entitled (Laghu) Mānasa, which contains knowledge pertaining to the planets, has been written in 60 ślokas ("verses in śloka or anuṣṭubh metre") by me. Those who will imitate it or find fault with it shall earn a bad reputation. (60)

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, 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 counterfeit works in imitation of this work shall earn infamy. For, no body can know the rationale etc. of the rules given in this Karaṇa work written by me, and therefore the learned people will easily know that such-and-such a 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 as it enables one to know the planetary motion mentally also without taking recourse to laborious computation, has been composed in 60 verses in anuṣṭubh metre. 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 reputation. What is meant is this: Although the mandocca etc. stated here (in this work) are a little different from those stated by Bhāskara II etc. even then this work should be studied by all as it follows other works and agrees with observations."

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

BIBLIOGRAPHY

A. Primary Sources

Āryabhaṭīya of Āryabhaṭa I (A.D. 499). Edited with English translation, explanatory and critical notes and comments etc. by K.S. Shukla and K.V. Sarma, I.N.S.A., New Delhi, 1976.

Bhāsvatī of Śatānanda (A.D. 1099). Edited with his own Hindi translation and illustrative examples by Matri Prasad Pandeya.

Bījagaṇita of Bhāskara II (A.D. 1150). Edited with the commentary of Kṛṣṇadaivajña (c. A.D. 1600) by V.D. Apte, Ānandāśrama Sanskrit Series (No. 99), Poona, 1930.

Brāhma-sphuṭa-siddhānta of Brahmagupta (A.D. 628).

(1) Edited with his own Sanskrit commentary by Sudhakar Dvivedi, Benaras, 1902.

(2) Text and commentary of Pṛthūdaka Svāmī (A.D. 864). Ms.

Bṛhat-Saṃhitā of Varāhamihira (d. A.D. 587).

(1) Edited with the commentary of Bhaṭṭotpala (A.D. 967) by Sudhakar Dvivedi, in 2 parts, (Part I: chs. 1-51; Part II: chs. 52-106), Vizianagram Sanskrit Series (Nos. 11, 12), Benaras, 1895, 1897.

(2) Translated into English by M. Ramakrishna Bhat, in 2 parts (Part I: chs. 1-57; Part II: chs. 58-107), Motilal Banarsidas, Delhi, 1986, 1987.

Gaṇakānanda of Sūryācārya (A.D. 1460). Ms.

Graha-cāra-nibandhana of Haridatta (or Haradatta). Edited by K.V. Sarma, K.S.R.I., Madras, 1954.

Graha-gaṇita-bhāskara of Tamma Yajyā (A.D. 1613). Ms.

Grahalāghava of Gaṇeśadaivajña (A.D. 1520)

(1) Edited with the commentaries of Mallāri, Viśvanātha and his own by Sudhakar Dvivedi, Bombay, 1934.

(2) Edited with his own Sanskrit commentary and Hindi translation by Sita Ram Jha, Second edition, Benaras, 1941.

(3) Edited with the commentary of Mallāri and his own Hindi translation by R.C. Pandeya, in 2 parts, (Part I: chs. 1-5: Part II: chs. 6-16), Jammu, 1977.

Grahaṇa-maṇḍana of Parameśvara (A.D. 1431). Edited and translated into English by K.V. Sarma, Hoshiarpur, 1965.

Grahaṇāṣṭaka of Parameśvara (A.D. 1431). Edited and translated into English by K.V. Sarma, K.S.R.I., Madras, 1961.

Karaṇa-kamala-mārtaṇḍa of Daśabala (A.D. 1058). Edited by David Pingree, Aligarh Oriental Series, No. 9, 1988.

Karaṇa-kutūhala of Bhāskara II (A.D. 1183). Edited with the commentary of Sumati Harṣa (A.D. 1619) by Mādhava Śastrī Purohita, Bombay, 1901.

Karaṇāmṛta of Citrabhānu (A.D. 1530). Edited by V.N. Namboodiri, Trivandrum Sanskrit Series (No. 240), 1975.

Karaṇottama of Acyuta Piṣāraṭi (d. A.D. 1621). Edited by K. Raghava Pillai, Trivandrum Sanskrit Series (No. 213), 1964.

Khaṇḍa-khādyaka of Brahmagupta (A.D. 665).

(1) Edited with the commentary of Pṛthūdaka Svāmī (A.D. 864) by P.C. Sengupta, Calcutta University, 1941.

(2) Translated into English with notes by P.C. Sengupta, Calcutta University, 1931.

(3) Edited with the commentary of Āmarāja (c.A.D. 1200) by Babua Misra, Calcutta University, 1925.

(4) Edited by Bina Chatterjee, in 2 parts, Part I: English translation and notes; Part II: Text with the commentary of Bhaṭṭotpala (A.D. 968), World Press, Calcutta, 1970.

Laghu-bhāskarīya of Bhāskara I (A.D. 629).

(1) Edited with the commentary of Śaṅkaranārāyaṇa (A.D. 869) by P.K. Narayana Pillai, Trivandrum Sanskrit Series (No. 162), 1949.

(2) Edited with English translation, explanatory and critical notes and comments etc. by K.S. Shukla, Lucknow University, 1963.

Laghumānasa of Mañjula or Mañjāla (A.D. 932).

(1) Edited with the commentary of Parameśvara, Ānandāśrama Sanskrit Series (No. 123), Poona, 1944.

(2) With Praśastidhara's commentary. Ms.

(3) With Sūryadeva Yajvā's commentary. Ms.

(4) With Yallaya's commentary. Ms.

(5) With Bhūdhara's commentary. Ms. Incomplete.

(6) With an anonymous commentary. Ms. Incomplete.

(7) With English translation and notes by N.K. Majumdar, Calcutta, 1951.

Lalla's Gola. Same as Golādhyāya of Lalla's Śiṣya-dhi-vṛddhida.

Mahā-bhāskarīya of Bhāskara I (A.D. 629). Edited with English translation, explanatory and critical notes and comments etc. by K.S. Shukla, Lucknow University, Lucknow, 1960.

Mahā-siddhānta of Āryabhaṭa II (c. A.D. 950).

(1) Edited with explanatory notes in Sanskrit by Sudhakar Dvivedi, Benares, 1910.

(2) Pūrva-bhāga, edited and translated into English, in 2 parts (Part I: Sanskrit text; Part II: English translation), Marburg, 1966.

Makaranda-sāraṇī of Makaranda (A.D. 1478). Edited with the commentary of Viśvanātha (A.D. 1629) and his own Hindi translation and notes by G.D. Tandon,Bombay, 1935.

Pañca-siddhāntikā of Varāhamihira (d. A.D. 587).

(1) Edited with an original commentary in Sanskrit by Sudhakar Dvivedi and English translation by G. Thibaut, Benares, 1889.

(2) Edited in 2 parts by O. Neugebauer and D. Pingree, Part I: Text and English translation by D. Pingree; Part II: Commentary in English by O. Neugebauer and D. Pingree, Kobenhavn, 1970, 1971.

Pāṭīgaṇita of Śrīdhara (c. A.D. 750). Edited with an ancient Sanskrit commentary, English translation and notes by K.S. Shukla, Lucknow University, 1959.

Rājamṛgāṅka of Bhoja (A.D. 1042). Edited by D. Pingree, Aligarh Oriental Series (No. 7), 1987.

Siddhānta-darpaṇa of Chandra Shekhar Singh (A.D. 1835). Edited by Joges Chandra Roy, Calcutta, 1899.

Siddhānta-saṃgraha of Vīrasūri (A.D. 1606). Ms.

Siddhānta-sāra of Mallaya Yajvā (A.D. 1596). Ms.

Siddhānta-śekhara of Śrīpati (c. A.D. 1039). Edited by Babua Misra, in 2 volumes, Vol. I (Calcutta, 1932) containing chs. i-xii of the text with the commentary of Makkibhaṭṭa (A.D. 1377) on chs. i-iv and that of the editor on the rest; Vol. II (1947) containing chs. xiii-xx of the text with the commentary of the editor.

Siddhānta-śiromaṇi of Bhāskara II (A.D. 1150).

(1) Edited by Bapu Deva Sastri and revised by Ganapati Deva Sastri, Benares, 1929.

(2) English translation of Gaṇitādhyāya along with notes by D.A. Somayaji, Tirupati, 1980.

(3) English translation of Golādhyāya by L. Wilkinson, revised by Bapu Deva Sastri, Calcutta, 1861.

Śiṣya-dhī-vṛddhida of Lalla.

(1) Edited with the commentary of Bhāskara II by C.B. Pandeya, Sanskrit University, Varanasi, 1981.

(2) Edited by Bina Chatterjee, in 2 parts, Part I containing Text with the commentary of Mallikārjuna Sūri (A.D. 1178) and Part II containing English translation and notes, I.N.S.A., New Delhi, 1971.

Sūkṣma-sphuṭa-siddhānta of G.C. Rautroy (A.D. 1988). Ms.

Sūrya-siddhānta.

(1) Edited with the commentary of Raṅganātha (A.D. 1640) by Jivanand Bhattacharya, Calcutta, 1891.

(2) Edited with the commentary of Parameśvara by K.S. Shukla, Lucknow University, 1957.

(3) English translation and notes by E. Burgess. Reprinted with an Introduction by P.C. Sengupta, Calcutta University, 1935.

Triśatikā of Śrīdhara (c. A.D. 750).

(1) Edited by Sudhakar Dvivedi, Benares, 1899.

(2) English translation by N. Rangacharia and G.R. Kaye, "The Triśatikā of Śrīdharācārya", Bibliotheca Mathematica, 13, 1912.

Vaṭeśvara-siddhānta of Vaṭeśvara (A.D. 904). Edited in 2 parts by K.S. Shukla, Part I containing Sanskrit Text and Part II English translation and commentary, I.N.S.A., New Delhi, 1986, 1987.

Vedāṅga-jyotiṣa of Lagadha.

(1) Yājuṣa-jyotiṣa with the Bhāṣyas of Somākara Śeṣa and Sudhākara Dvivedī and Ārca-jyotiṣa with the Bhāṣya of Sudhākara Dvivedī and explanatory notes of Murlidhara Jha, Benares, 1908.

(2) Edited with his own English translation and Sanskrit commentary by R. Shamasastry, Mysore, 1936.

(3) Edited with English translation and notes by T.S. Kuppanna Sastry, I.N.S.A., New Delhi, 1985.

B. SECONDARY SOURCES

Bag, A.K., Mathematics in Ancient and Medieval India, Varanasi, 1979.

Billard, Roger, L'Astronomie Indienne, Paris, 1971.

Bose, D.M., etc. (Editors), A Concise History of Science, I.N.S.A., New Delhi, 1971.

Cunningham, A., Ancient Geography of India, Calcutta, 1924.

Dey, N.L., Geographical Dictionary of Ancient and Medieval India, London, 1927

Dikshit, Shankar Balakrishna, Bhāratīya Jyotiṣaśāstra (in Marathi) Second edition, Poona, 1931; Hindi translation by S.N. Jharkhandi, Hindi Samiti, Lucknow, 1963; English translation, in 2 parts, by R.V. Vaidya, Delhi, 1969, 1981.

Dvivedi, Sudhakar, Gaṇaka-taranginī (in Sanskrit), edited by Padmakar Dvivedi, Benares, 1933.

Godfray, H., An elementary treatise on lunar theory, 1871.

Krishna Ayyar, K.V., A history of Kerala, Second edition, Coimbatore, 1968.

Kuppanna Sastry, T.S., Collected Papers on Jyotiṣa, Tirupati, 1989.

Mukhopadhyaya, D., The Evection and the Variation of the Moon in Hindu Astronomy, Bull. Cal. Math. Soc., 22, 1930, 121-132.

Neugebauer, O., A History of Ancient Mathematical Astronomy, in 3 parts, Springer-Verlag, 1975.

Pandeya, Shreecandra, Grahagati Kā Kramika Vikāsa, Krishnadas Sanskrit Series (No. 14), Krishnadas Academy, Varanasi, 1981.

Pederson, Olaf, A Survey of the Almagest, Odense University Press, 1974.

Pingree, D., Census of the Exact Sciences in Sanskrit, Series A, Nos. 1, 2, 3, 4, American Philosophical Society, Philadelphia, 1970, 1971, 1976, 1981.

Sarma, K.V., A History of the Kerala School of Hindu Astronomy, Vishveshvaranand Institute, Hoshiarpur, 1972.

Sen, S.N., Bag, A.K., Sarma, S.R., A Bibliography of Sanskrit Works on Mathematics and Astronomy, I.N.S.A., New Delhi, 1966.

Shukla, K.S., The Evection and the Deficit of the Equation of the Centre of the Moon in Hindu Astronomy, Proc. of the Benaras Math. Soc., New Series, Vol. VII, No. 2, Dec. 1945.

Smart, W.M., Text-book on Spherical Astronomy, Cambridge, 1940.

Smith, D.E., History of Mathematics, 2 vols., Dover Publications, New York, 1958.

Srinivasiengar, C.M., The history of ancient Indian mathematics, World Press, Calcutta, 1967.

Swamikannu Pillai, L.D., An Indian Ephemeris, A.D. 700 to A.D. 1799, 6 vols., Reprinted, Agam Publications, Delhi, 1982.

Teliaferro, R. Catesby. Translation of Ptolemy's Almagest, Great Books of the Western World, vol. 16, University of Chicago, 1952.

Toomer, G.J., Ptolemy's Almagest, Springer-Verlag, 1984.