BHĀSKARA I AND HIS WORKS

PART II

MAHĀ-BHĀSKARIYĀ
PREFACE

The object of the "Hindu Astronomical and Mathematical Texts Series" is to bring out authoritative and critical editions of important unpublished works dealing with ancient Indian astronomy and mathematics. The present edition of Bhāskara I's *Mahā-Bhāskarīya* is No. 3 of this series.

The idea of bringing out the above series is due to Dr. A. N. Singh, late Professor of Mathematics, Lucknow University, who organised a scheme of research in the history of Hindu mathematics and astronomy in the Department of Mathematics, Lucknow University, with the object of collecting, studying, and editing important works on Hindu mathematics and astronomy. Under his able guidance remarkable progress was made in this direction and a number of manuscripts were acquired, studied and edited. In 1954 he submitted to the Government of the Uttar Pradesh a detailed plan for the publication of the work carried out under the above scheme of research in a series to be called the "Hindu Astronomical and Mathematical Texts Series". The plan was approved by the Government and a sum of Rs. 1000/- was sanctioned in the name of Bhārata Gaṇita Parisad to undertake the publication of the series. In the year 1955 the Government of the Uttar Pradesh was generous enough to sanction the remaining sum of Rs. 9000/- to the Department of Mathematics and Astronomy, Lucknow University, for the said publication.

The scheme of research in the history of Indian mathematics and astronomy referred to above has been financed by the Government of the Uttar Pradesh through the kind help of Dr. Sampurnanand, its then Education Minister, for which we express our sincere thanks to them. We are specially grateful to Dr. Sampurnanand who, a great scholar of Jyotisa as he himself is, has been taking keen interest in the progress of this research and helping us with necessary funds and encouragement from time to time.

R. Ballabh
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VOWELS

Short: अ इ उ ए ऒ ओ ह
      a  i  u  e  o  oh

Long: आ ई ऊ ए ऐ ओ ओ ह
       aː  iː  uː  eː  ai  oː  oː h

Anusvāra: — = m

Visarga: : = h

Non-aspirant: s = '  

CONSONANTS

Classified: क ख ग घ ङ च छ ज झ ञ ट ठ ड ढ ण त थ द ध न ति थि दि धि नि
           k  kh  g  gh  n  ch  jh  jh  n  t  th  d  dh  n  ti  th  dh  ni

Unclassified: य र ल व श ष स ध ह
               y  r  l  v  s  sh  s  dh h

Compound: ख s  tr  jn
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>Ā</td>
<td>Āryabhaṭīya</td>
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<tr>
<td>BJ</td>
<td>Bhāj-jātaka</td>
</tr>
<tr>
<td>BrSpSi</td>
<td>Brāhma-sphuta-siddhānta</td>
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<td>BrSaṁ</td>
<td>Bhāt-samhitā</td>
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<td>GL</td>
<td>Graha-tāghara</td>
</tr>
<tr>
<td>KK</td>
<td>Khaṇḍa-khaḍyaka</td>
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<tr>
<td>KKau</td>
<td>Karaṇa-kaustubha</td>
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<tr>
<td>KKu</td>
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<td>KPr</td>
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<td>Laghu-Bhāskariya</td>
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<td>LMā</td>
<td>Laghu-mānasā</td>
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<td>MBh</td>
<td>Mahā-Bhāskariya</td>
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<td>MSi</td>
<td>Mahā-siddhānta</td>
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<tr>
<td>MuCi</td>
<td>Muhūrta-cintāmaṇi</td>
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<td>PiSi</td>
<td>Pīṭamahā-siddhānta (of Viṣṇudharmottara-purāṇa)</td>
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<td>PSi</td>
<td>Paṇca-siddhāntikā</td>
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<td>Siddhānta-tatva-viveka</td>
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<td>ŚuŚi</td>
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<tr>
<td>VVŚi</td>
<td>Vṛddha-Vasiṣṭha-siddhānta</td>
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INTRODUCTION

This Part\(^1\) contains the text with English translation, notes, short comments, and explanations, where necessary, of the Mahā-Bhāskarīya ("the bigger work of Bhāskara I").\(^2\)

Sanskrit Text. The text has been edited on the basis of the following five manuscripts collected by the late Dr. A. N. Singh:

MSS. A and B — Containing the text only;

MS. C — Containing the text together with a commentary entitled Bhāsya of Govinda Svāmī;

\(^1\) The present work has been divided into four parts: Part I—General Introduction (containing a general study of the life and works of Bhāskara I); Part II—Mahā-Bhāskarīya; Part III—Laghu-Bhāskarīya ("The smaller work of Bhāskara I") edited with English translation, critical notes and comments, etc.; Part IV—Bhāskara I’s commentary on the Āryabhaṭīya of Āryabhaṭa I.

\(^2\) Bhāskara I, the author of the Mahā-Bhāskarīya, was a different person from his namesake of the twelfth century A. D., the author of the Siddhānta-śīromāṇi and Lilāvatī, etc. He lived in the seventh century of the Christian era and was a contemporary of Brahmagupta (628 A. D). He wrote three works on astronomy which were composed in the following order: (1) the Mahā-Bhāskarīya, (2) a commentary on the Āryabhaṭīya, and (3) the Laghu-Bhāskarīya. His commentary on the Āryabhaṭīya was written in 629 A. D., i. e., one year after the completion of the Brahma-sphuṭa-siddhānta of Brahmagupta.

Bhāskara I was a follower of Āryabhaṭa I, the author of the Āryabhaṭīya. His works provide us with a detailed exposition of the astronomical methods taught by Āryabhaṭa I and throw light on the development of astronomy during the sixth and early seventh century A. D. in India. For details regarding the life and works of Bhāskara I, the reader is referred to Part I of the present work.
MS. D —Containing a commentary known as Prayoga-racanā and also supplying the beginnings of the passages commented upon;

MS. E —Containing the commentary Karma-dīpikā of Parameśvara and also the beginnings of the passages commented upon.

MSS. A and B, which contain the text only, are in agreement in so far as the extent of the two is concerned. In other respects also they are almost the same. Both of them contain 396 verses. Agreement between the two manuscripts seems to indicate that they are perhaps derived from the same source. There are other reasons also for this conjecture. Verse iii. 45, which has been misplaced in one of them, occupies the same wrong position in the other also. Moreover, six and a half verses⁰, which have been commented upon by Govinda Svāmī (MS. C), Parameśvara (MS. E), and in the Prayoga-racanā (MS. D), and are included in the text of MS. C, are absent from both MSS. A and B.

MS. C contains 394 and a half verses. Its text has evident gaps at some places, for a few verses, some of which have been actually commented upon in the commentary at their proper places, are missing from the text. These are amongst those verses which belong to MSS. A and B and have been explained in the Prayoga-racanā (MS. D), and in the commentary of Parameśvara (MS. E).

MSS. D and E contain commentaries of the Mahā-Bhāskarīya. In these manuscripts only the beginnings of the passages commented have been given; the full text is not given.

The following table will show at a glance how far the above manuscripts have differed from one another:

¹ viz. i. 12; v. 18, 26-27(i), 47-48(i); vi, 14(ii)-15(i), 58(ii).
<table>
<thead>
<tr>
<th>Chapters and verses of the edited text</th>
<th>Whether available in MSS. A and B?</th>
<th>MSC Whether available in the Text?</th>
<th>MSC Whether commented upon in MS. D?</th>
<th>Whether commented upon in MS. E?</th>
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<td>Verse 8</td>
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<td>Verses 9-11</td>
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<td>Verses 13-52</td>
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<td><strong>Chapter VII</strong></td>
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<td>&quot;</td>
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The edited text of the *Mahā-Bhāskarīya* contains 402 and a half verses, of which 387 and a half occur in all manuscripts. The remaining fifteen verses, which occur either in MSS. A and B or in MS. C, are of the following categories:

(1) Those which have been commented upon by all commentators, viz. i. 8, 12; iii. 75(i); iv. 2(i); v. 18, 26-27(i), 47-48(i); vi. 14(ii)-15(i), 19(i), 26, 36(ii), 41, and 58(ii).

(2) Those which have been commented upon in one or two commentaries only, viz. iii. 74(ii); iv. 13; viii. 23-24.

Inclusion in the edited text of the verses of the first category requires no explanation. Those of the second category have been taken as genuine for the following reasons:

Half-verse iii. 74(ii). This has been regarded as genuine because it is relevant to the context and the subject matter contained in it has its counterpart in the author’s smaller work, the *Laṅgu-Bhāskarīya*. It occurs in MSS. A and B and forms part of a passage [vv. 71-75(i)] which describes the occultation of certain stars by the Moon. This description is a statement of facts and hardly requires any explanation, which explains why the half-verse in question has been left unexplained by Govinda Svāmī and Parameśvara. The author of the commentary *Prayoga-racanā* has simply paraphrased it.

Verse iv. 13. The genuineness of this verse is evident from the mention of the word "*athavā*" (meaning "or") in the beginning of the next verse 14, which shows that verse 14 gives an alternative method. Verse 13 is thus indispensable, for if it is removed verse 14 would no longer be an alternative method. The author of the *Prayoga-racanā*, commenting on these two verses, states:
INTRODUCTION

“viśkambhārdha etc. Here the author finds the true daily motion.”¹

“antyajīvā etc. This is an alternative method.”²

So also, commenting upon the verse 14, Paramesvara writes:

“The author sets forth the method of finding the true daily motion by another method.”³

Absence of the verse in question from the text of MS. C seems to be due to the carelessness of the scribe.

Verses viii. 23-24. These verses are taken as genuine because they occur in MSS. A and B and have been mentioned in MSS. D and E. Moreover, they have been mentioned and the examples contained therein have been solved in MS. C in Chapter I under verses 49 and 50 respectively. It seems that like so many other verses these also have been left out from MS. C due to the carelessness of the scribe. There is no doubt that they were composed by Bhāskara I, because they occur in his commentary on the Āryabhatīya along with several other verses containing similar examples.

There is one more verse which requires consideration here. It is not included in the numbered verses of the edited text. This verse marked 24* occurs after verse 24 of Chapter VIII. It does not occur in any of the available manuscripts of the Mahā-Bhāskarīya, but I have taken the liberty to include it in the edited text, though I have not given it any specific number. My reasons for including this verse in the text are as follows:

(1) The preceding verse 24 contains an example which

¹ विभक्तमभांचनेति स्कुटमुक्ति सावधलि ।
² अन्त्यजीवैवयुपायातरम् ।
³ स्कुटमुक्तिवल्यान्य प्रकारात्तर्तेनवाह ।
unlike other examples of that chapter, is of an abstract nature. In order to give that example a concrete form, it is necessary to supply some such data as mentioned in verse 24*.

(2) Verse 24 occurs in Bhāskara I's commentary on the Āryabhaṭīya and in Govinda Śvāmī's commentary on the Mahā-Bhāskariya. At both the places it has been followed by verse 24* and the two verses taken together are treated as forming one complete example. The example has been solved both by Bhāskara I and Govinda Śvāmī.

Counting this additional verse also, the edited text of the Mahā-Bhāskariya consists of 403 and a half verses, which are distributed over the eight chapters as follows:

<table>
<thead>
<tr>
<th>Chapters</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verses</td>
<td>52</td>
<td>10</td>
<td>74</td>
<td>64</td>
<td>78</td>
<td>62</td>
<td>35</td>
<td>28</td>
</tr>
</tbody>
</table>

Reading-differences. The question of deciding between differing readings of the text as encountered in the manuscripts consulted by me has in general not presented much difficulty. In my choice between alternative readings I have been guided solely by the criterion of appropriateness. My task has been simplified by the fact that the readings selected and accepted should give the correct mathematical interpretation of the text as well as should fit in the metre.3 Quotations from the Mahā-Bhāskariya are found in other works. I have gathered together such quotations and this has helped me to verify the edited text in a number of cases.

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1 ii. 32-33.
2 i. 52.
3 Metres used in the Mahā-Bhāskariya have been arranged alphabetically at the end of the Sanskrit portion.
In some cases, however, alternative readings are possible and it may be that I have not given in the edited text the readings which might have occurred in the original. I have given in the foot-notes all alternative readings found in the various manuscripts consulted by me so that the interested reader may for himself decide whether the readings given in the edited text are appropriate or not.

*English Translation.* The question of translating technical material written in Sanskrit into English presents considerable difficulty. It requires a thorough knowledge of both languages which few can claim. My effort has been directed towards giving as far as possible a literal version in English of the text. The portions of the English translation enclosed within brackets do not occur in the text and have been given in the translation to make it understandable, and at places are explanatory. Without these portions the translation at places would appear meaningless to a reader who cannot consult the original for lack of knowledge of Sanskrit. I have tried my best to keep the spirit of the original and have as far as possible not altered the sequence in the translation. Sanskrit technical terms having no equivalents in English have been given as such in the translation. They are explained in the subjoined notes and the reader can always refer to the Glossary given in the end to find the meaning of such terms whenever the subjoined note does not contain the explanation of the terms.

Verses dealing with the same topic have been translated together and are preceded by an introductory heading briefly summarising their contents. In doing so I have followed the practice of the commentators.

The translation is followed by short notes and comments comprising (i) elucidation of the text where necessary, (ii) *rationale* of the rule given in the text, (iii) critical notes, and (iv) other relevant matter, depending on the nature of the passage translated.
Technical Terms. I have already pointed out (in Part I) the peculiarities of the language of the Mahā-Bhāskariya. I have also noted that some of the technical terms used therein do not occur in other works. These technical terms are not found in Sanskrit lexicons, and I have succeeded in arriving at their correct interpretation and meaning by (i) the context, and (ii) comparison of the same or similar topics in other works available to me. The commentaries consulted by me have been of immense help, for without them quite a number of passages in the text would have remained obscure. In the foot-notes I have given references to parallel or similar passages found elsewhere, so that the reader may judge for himself whether I have arrived at correct interpretations or not.

At the end of this Part I have appended (1) a list of passages from the Mahā-Bhāskariya quoted by later writers, and (2) a Glossary of terms used in the Mahā-Bhāskariya.

In the end it is my sacred duty to express my great indebtedness to the late Dr. A. N. Singh for the help and guidance that I received from him in the preparation of the present edition of the Mahā-Bhāskariya. I am also under great obligation to the late Dr. Bibhutibhusan Datta (alias Swami Vidyaranya) who kindly went through the whole of this work and gave valuable suggestions and advice.

My sincere thanks are due to Dr. Ram Ballabh, Professor of Mathematics, Lucknow University, for his suggestions and advice from time to time and for affording me all facilities in my researches. I am also thankful to Sri Gopal Dwivedi, Jyotisacharya, and Sri Markandeya Misra, Jyotisacharya, my Research Assistants, for the assistance rendered by them to me.

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K. S. Shukla
श्रीमद्भास्कराचार्यप्रणीतम्

महाभास्करीयम्

—०—

प्रथमोद्धायः

कलां विभाति क्षणाकरस्य वः
प्रकाशिताशा चिरसा गम्भीरतिमः।
नमोऽस्तु तस्मै सुरत्वितादस्ये
समस्तविद्याप्रभवाय शम्भवे॥ ९ ॥

जयति भानोऽ सकलाव्योऽधिनः
कराः हिमांशोवेणिनः नानाधिशः॥

लघुरितार्क्षुपुठशर्मयो
धरासुतक्षिणितदिशः॥ २ ॥

तपोभिराभ्यं स्पृहांसत्तकाद्यकरः
विग्रहविद्वेदं जगसु सद्दुः॥

चिन्ते च जीव्यासुरपेतकलयाः
भटस्य शिष्या जितिरारकावः॥ ३ ॥

नवाद्रिक्रिष्णविनियोऽः सहिन्द्रां
शकेदन्तरामां गत्वार्थेसङ्ग्रहम्।

द्विषक्रिष्णं गत्वात्मसंधियुतं
युगाधिमासीगृपणेवदं द्विराशितम्॥ ५ ॥

'ब्रमसिद्धं B. 'हिमाशोवेणिति...'तत्त्विष्य: A, B. 'धरासुतक्षिणितिविव: A, B.
'स्पृहांसत्तकाद्यकरः C. 'चिन्ते सम्भयेतु A, B. 'जीव्यासुरपेतकलयाः A, B. 'नवाद्रिक्रिष्णविनियोऽः A, B; नवाद्रिक्रिष्णविनियोऽः C. 'युगाधिन्मासीगृपणेदं द्विराशितम् B; युगाधिन्मासीगृपणेदं द्विराशितकम् C.
युगाक्षमास्थानायाधिमार्गकरी
युगात् तिथिः गतवस्तीयूतम्।
गुणमैतर्थो गुणवेदु हिरार्शिवं
निशाकरहृविभजेत नित्याः। ॥ ५ ॥
तिथिप्राणाशापितस्तो विषोधिते
भवत्यांहि निचयः कलेवरः। ॥ ६ ॥
वदलि वारं दिवनसुनुप्रजितात्
प्रवृत्तिमयःहुद्धदचतो रवे:। ॥ ৭ ॥
शशाक्षमासेरभितांतात् हरे
दत्तातमासानन्याकसमभवे। ॥
'दीनोऽक्षरान् भूमितिनेहःतान् दिने
विभज्य लब्ध्यशास्त्रशैर्धरणः। ॥ ৮ ॥
उदारितान् धान्यभगान् क्षमादिने
लभामेत कानु कलियात्वासरे॥।
इति प्रलब्धा भगाप्रस्तत: कमादृ
शूद्धालिप्ताविकला:। सत्तवरा:। ॥ ९ ॥
कलिक्षणं वा ससें दिवाकरः
स्त्वार्यात्थतैर्मण्डगः समाहतम्। ॥
भजेत विमयसहस्रावत्थ्योदिते
विह्रुःमानां परवद्तं लिितिका:। ॥ १० ॥
निशाकरं वा ग्रहमुच्छतिम वा
कलिक्षणं।' ततस्मायात्मण्डलः। ॥

"युत: A; पु: B. "The word तिथि here means 30, and not 15 as usual. "गतवस्तीयूतम् A, B; हिरार्शिव A, B; हिरार्शिक C. "विशो
ध्ये A, B; भवनित A, B; तिथिसुनुप्रजितात् A, B; शशिमासेरभितांतात् C. "दीनोऽक्षरान् भूमितिनेहःतान् A; दीनोऽक्षरान् भूमितिनेहःतान् B, C. "उदारितान् धान्यभगान् क्षमादिने: लभामेत कानु कलियात्वासरे:। इति प्रलब्धा भगाप्रस्तत: कमादृ
शूद्धालिप्ताविकला:। सत्तवरा:। "कलिक्षणं वा ससें दिवाकरः स्त्वार्यात्थतैर्मण्डगः समाहतम्। "भजेत विमयसहस्रावत्थ्योदिते
विह्रुःमानां परवद्तं लिितिका:। "निशाकरं वा ग्रहमुच्छतिम "कलिक्षणं।' ततस्मायात्मण्डलः। ॥" [ससम् ( = समाभि: शह सतेमान, ससम्) means "together with years"]
यषेष्टनक्षत्रगणौं हरेत॥
तदीयनक्षत्रगणस्तत्रः कला: ॥१०॥
युगाधिमस्वऽवृणं हरेत् हरेवः
क्षमादिनेवं भगणादि लभ्यते।
स्रोदशाधेष सवितर्यथः किष्पे:
मन्योशिनिनांपतिचारसिद्धे॥११॥
कुमुदलीनां सुहदोववातां
विशोध्य शेषस्य लबस्त्रयोदशः॥
स मध्यमाकों गणौर्निर्वस्ते
गुरुसादात्मस्यज्ञुट्टुडुम्बिर्भ: ॥१२॥
विना चुराशर्यः चन्द्रभाष्करी
प्रकृवत्ते वा विविरेय कथ्यते।
समासु मातीस्तववर्षायामु ये
हरतीसमसा विनियोज्य ताः 'पुनः' ॥१३॥
रामचन्द्रनान् दिवसेषु योजयेद्
गतेषु मासवर्ष ततोधिमासकः॥
निःत्व सवः विभजेत सवंदा
युगाकामासौ दिवस्तवमागते: ॥१४॥
भवति लक्ष्मास्तवधिमासः: पुनः
स्तोथोपनिवासु च भागहारकः।
भजेत रोषेण शिशिमाससंहितः
ततोऽणुवतिविकलः: सतततरः॥१५॥
ततोधिमासानु प्रणिःत्व चानिनिभी
नियोज्यं सम्यगस्तवसर: यमात्।
युगाधिमसनांविधिबत्तुद्यैः
तमस शेषं प्रवदत्व चालिह्नमु॥१६॥

\(\text{a}\); \(\text{b}\); \(\text{c}\); \(\text{d}\); \(\text{e}\); \(\text{f}\); \(\text{g}\); \(\text{h}\); \(\text{i}\); \(\text{j}\); \(\text{k}\); \(\text{l}\); \(\text{m}\); \(\text{n}\); \(\text{o}\); \(\text{p}\); \(\text{q}\); \(\text{r}\); \(\text{s}\); \(\text{t}\); \(\text{u}\); \(\text{v}\); \(\text{w}\); \(\text{x}\); \(\text{y}\); \(\text{z}\).}
हर्वाधिभाषणसरस्वतम् किं वर्ण
हिरवा धराय दिवसे प्रलब्धम्
संस्कृत्य नित्यं व्यवमाताशे मके पुनः रन्नकरण्येवोक्तम्।
मुन्नारसिद्धेरणोदिनेंहृस्तु-शिःह्व ण्यायामोक्तमार्थिकम्।
कला विलिपता क्रमशतत्परा-स्तवतीतमासा दिवसा गृहांशकः।
योदशाचायापि रूपाविहितः द्रिशियहेतुवविधारणसोजनम्।
निषादकरको गणके प्रकीतिती महत्त्विते साधितमाने।
अम्बरोपवितिहविभाजितो मृदैनेयदसोजनानि ले।
तुम्बुगुणम् दिवसांनावहेतु कक्षया भगणरायं स्वया।
अशुक्तमोदरिदमांकीये।
कर्म प्रहाणां तद्विन्द्रसिद्धम्。
सिद्धचतुर्थ शास्त्रार्थमांकीयी-
मुदृष्टत्वें तत् रहस्यभूतम्।
इति सहस्रहृदयमणकलेशः हुत्वा वर्षीण राधवसुविकलमासंसद्वः।
युक्तवः सदा प्रविधिप्रहच्छ थरान्नकाते
मीरा मरणिति दिवसांचे हुतेवज्ञिण्या।
फुंडाण राधामयवै रसारामभागे।
भूयोनिजनेदुगुणितेऽहुरेच्छ भागम्।

खण्डोमयाकम्बुमिनभिःः प्रवर्तितयीयौ
संयोजय भूतयमहद्ध्वः दिनाति ॥२३॥
तेष्योपविधिकामान्यविशेषयःः शेषं
पालादतीतीः १ वृमसंय कःः
यदा न शुच्येदवम् प्रगृहः
दल्वा चतुष्पददिमतोः विशेषयः ॥२४॥
मासाधिमासकःक्यायादैः ० धिरिभागशेषाः-
तिरवादगुणाद्वध्योम्यमुद्योयते: ।
शैवालिखितकविलयतिमोषुप्रणीण्यः
संयोजय हृदकिर्तिसेषु नगावशेषः ॥२५॥
एकुत्तरदिवशेषु वर्षपः
"कौिति: स्तिक्षगादित तद्विदा ।
हृदनार्तारगतस्वस्वसरादृः
वेदवन्कविुपतस्वतः"वमः ॥२६॥
वर्षेपु रङ्गमाधित्तबहितेपुः
पद्यपपचविवृहदेषु विदाणिलामः ।
ते योजिता दंशहतामुः "समायु संजाः
सम्प्रातुवित्ति रविजा इति निर्बहो" मे ॥२७॥
रविजिदिवशयोज्याश्चावमः" येऴः" लब्धा:
सततमविश्वमासाध्वोद्वेषु" खानिनिन्नानुः ।
भवति यदवशिष्टशोधनीयः समायाः
यदि तदभिक्षुपः बोधेयश्चोपविष्टम् ॥२८॥

'खण्डोमयाकम्बुमिनभिः प्रवर्तितयीयौ A; खण्डोमयाकम्बुमिनभिः प्रवर्तितयीयौ B; तेष्योपविधिकामान्यविशेषयःः शेषं A, B; तेष्योपविधिकामान्यविशेषयःः C. 'वालादतीतोः A, B.
कःः B. "शुच्येदवम् B. "दल्वा चतुष्पददिमतोः A, B; मासाधिमासकःक्यायादैः ० धिरिभागशेषाः-
तिरवादगुणाद्वध्योम्यमुद्योयते: । A, B; मासाधिमासकःक्यायादैः ० धिरिभागशेषाः A, B; द Missing from C.
नगावशेषम् A, B. "कौितित: स्तिक्षगादित्तदिता A; कौितित्स्तिक्षगादित्तदिता D B.
सपः B. "रङ्गमाधित्तबहितेपुः C. "समायुसमाः A, B; समायुसमाः C.
निश्चलो A, B. "चापः B. "यश A, C. "सततमविश्वमासाध्वोद्वेषु ॥'सपः C. "शोधनीयः A, B.
堑्योक्तात्रकान्यो वर्षगणो यहंतुः सदा कथितः।
तेन समेता विहगं ध्रुवका इति कीतितः। सद्यम्। ॥ १९॥
मघुसिद्धनितयार्हो हीनान्धो गणोऽहस्ता
दिविचरहृतशिष्टो वारामाहाबद्धपादि।
अत इद्यमपि शोध्यं शोधनीयं समयाः
पतिष्तमतिरिक्तो गृह्येते नापरोऽरे ॥ ३०॥
सप्तत्त्वदिवसाश्रयश्रभागाः दिहुगणिता विषंकाश्च।
तद्रहितो ग्रह्येते रविवुधभुगवश्च निरोष्ट:। ॥ ३१॥
कुमुदवनसुबन्धो राशिवर्गों दियुक्तो
श्रहतुगणारो भागारः प्रविष्टः।
शरयममलाखस्यो भागान्वोऽरे लाभो
‘हृद्युण्मपि शिविनिच्छे बेन्द्रियापता विलितः। ॥ ३२॥
भागा: ब्राह्मणाश्रयश्रिण्युगणिते‘, विलितिका खेयः।
प्रिन्ध:। शताविनको विशालया रविश्च तम:। ॥ ३३॥
अचलहत्तवांशा लिंगिका स्वर्णिये
‘गणरसविभरो लिंगकात्सा विपुर्वः।
प्रहतुगणमानांसत्तपरा: शोधनीया
दसावससमवेत्वश्रन्दृशः स भानो:। ॥ ३४॥
भृभुध्रामहतां हरेर्चल्लगुरुः।’’रविवुधारणां तन्नु
’’भागास्फुजितो विमौलिकागणा’’ भागे शतेनोपधुः।
रामांतो युं रविश्च सकलं शिवनाग्रेष्योधये
व्येश: सोमजसोमया: कुतुण्ड: सूयाण्ड: विशवाह:। ॥ ३५॥
अवोभूधनेनभाजिते फलं
राष्योष्ट्वाभाजितेष्य लिंगिकः।’’

‘तेन Missing from C. ’ विभागा C. ’ ध्रुवका इति कीतित: B. ’ वारामान्यावादि: A, B. ’ सप्तत्त्वदिवसाश्रयभागाः C. ’ हृद्युण्मविशिष्यिनिच्छे बेन्द्रियापता: A; हृद्युण्मविशिष्यिनिच्छे बेन्द्रियापता विलितः: B. ’ ब्राह्मणाश्रयश्रिण्युगणिते A; ब्राह्मणाश्रयश्रिण्युगणिते C. ’ गणरसविभरो लिंगकात्सा विपुर्वः: A, B. ’ ‘समृद्ध: A, B. ’ हरेर्चल्लगुरुः A, B. ’ ‘प्रहराणाम C. ’ ‘भागास्फुजितो विमौलिकागणा A, B;’ भागास्फुजितो विमौलिकागणा C. ’ ‘विमौलिकागणा: means विलिताण्डः:। ’ लिंगिका खेयः A, B.
गृहार्ध्याय:]

"बन्दुक्षबृहते विलिपिका बिदुः।
सप्तमेव योज्य गण्यते वुः। ॥ ३६॥।
अष्टाहेऽति धारयमारिवहते कला: स्युः।
‘दैह तथा निविदिम्भकात्विलिपिकाश।
युक्ताप्तेवेत्तुवंशयं शासितं गणये।
‘ दिविन्दत्वो रक्षिष्यो धनमजन कार्यम् ॥ ३७॥।
‘ दैविन्दचेव ग्रहदेहे स्वविशाभागरहते।
तु लिपताभा:।
पवलाशदिविलिपितकला।। क्षेत्रम्।
‘ ब्राम्मीर रावरेरः। ॥ ३८॥।
‘ दिविन्दचेव ग्रहदेहे शरसगरामोद्वृत्ते।
तु लिपताभा:।
‘ बुरांमधुरारोंगो रक्षिष्योगाधिशाङ्कुतः। ॥ ३९॥।
‘ राशिवर्ग क्षिप निवारकसुतुवंधने।
“पातं निपायतं भग्नानुः” क्षिप राशिष्टकम्।
‘ तैराविकागतिदिनेतु' च रूपसेरकं।
' स्वार्थायनं' गणका भविषासत्वताः। ॥ ४०॥।
‘ भुदानिष्टथा' स्योऽन्यामकबलोणेण भाजितै।
‘ हारभाज्ञो दृती स्वातां कुटाकारं तयोऽविवृत्। ॥ ४१॥।
‘ भाज्ञो न्येवेऽपिर हारमवत्ति तत्स्य
खण्डचालवचपरमप्रमो विनिदाय वल्लयः।
‘ केनाश्चेतोपमपनीयः’ यथार्थ सङ्केतः।
‘ भागेऽदेशानि परिश्राव्यमिति प्रभुवत्स्यम्। ॥ ४२॥।
‘ आप्तां मति तां विनिदाय वल्लयं।
‘नित्यं हायः: कमशाशच लघुम्। ॥

1 बन्दुक्षबृहते विलिपिका बिदुः: सप्तमेव योज्यते A; विन्दय्या.... ते विलिपिका
'दिवसस्मृतेऽविलिपिकाश् A, B; सदात्तात्मस्मृतात्मिनितिकाश् C।
" मुक्तविद्धेवामयं A; मुक्तविद्धेवामयं C।
" गण्यम्: A, B। " स्वविशावः
‘भागरहिते A, B। " सप्ताशदिविलिपिकला। A, B। " क्षेत्रम्।
‘ स्युः। " रावरेरः। " शान्ताङ्गेषु शान्ताङ्गेषु A, B।
" क्षेत्रम्। " स्युः। " भग्नानुः। " तैराविकागतिदिनेषु A।
" प्रावत्तमिति C। " मुक्तिविद्धेषु A, B; मुक्तिविद्धेषु समाधिस्तानो C।
" वल्लयः: A, B। " तेनास्तोऽधनपनीय A, B। " The reading स्युः in place of ‘स्युः has been
mentioned by Govinda Svāmī in his commentary। " प्रचलय A, B.
" भोजः" .......तिस्रा A; अवंतं तिस्ता B। " नीत्य A.
मत्य हर्तं स्वादुपरिचितं यज्ञशेषं युक्तं परस्त्र तद्गतः ॥४३॥
हरेण मात्रस विदिनोपरिश्रोत्रो
भाज्येन निषयं तदधृष्टस्तं ॥
अद्वांशोऽसिद्धं भगणादयक्ष
तथा संवेद्यस्य समीहतं यत् ॥४४॥
रूपमेकमप्याप्पि कुष्टाकारः प्रसाद्यते ॥
गुणकारोऽऽशक्तं च राशिः स्वातामपुरयं धारणं ॥४५॥
इष्टेन शेषममिहतं षेषेदुःष्ट्यां
षेषं दिनानि भगणादिं च तीर्यतेऽव ॥
रायशाद्रो निरपरिवित्तवासरथान ॥
रायवतिमानवमिजाः प्रवदति शोषम् ॥४६॥
भाज्योधिको यदि भवेतु खलु हारारात्स
स्तवारिकं समपनीय लघृव कर्म ॥
तेनाधिकेन गुणितो गुणकारार्धिः
युक्तोऽहस्तेन स भवेतु पृथग्ग लघृम् ॥४७॥
अपवर्तितवासरादिशेषातु
कमक्षत्तापनोह रूपपूर्वम् ॥
कुलकुटंलब्धवराशिभेषां
गुणकारं समुपांति वार्षेऽति ॥४८॥
छेदभाज्यवर्तनं यष्ठेदस्यातिरिच्यते ॥
तेन हारं समभस्य वेलाकुटंस्तु पूर्ववस्तु ॥४९॥
प्रक्ष्य्य भागहारं कुट्टाकारे पुनं पुनं ॥ प्राणीः ॥
योज्यं च भागलञ्च भाष्येः प्रस्तारपुक्त्येव ॥५०॥
गृहव्यवस्थां यदि कस्प्रिचत्स्वादेः
गृहव्यवस्थागादित्सेव कर्म ॥
रूपण वा योज्य विभिन्नविचित्रः
सर्व समानै खलु लक्षणेन ॥४.१॥
योगेषु तेषां भगणादियोगे—
विशेषविशेषम् तथा विशेषः ॥
अन्योत्योपादिपि चिन्तनीयः
मिष्टप्रहस्तपश्चर्गविधानम् ॥४.२॥

इति महाभाष्करीये भ्रमोपद्यायः।

"योग्यविभिन्नविचित्र्य A, B. "विशेषः C."
हिन्दीयोगध्यायः

लक्ष्णात: खरनगरे सितोलानेुः
पाणाटों भिन्निपुरी तथा तपानीः।

उत्तमसितवर्तनापेशीलो

लक्ष्मीविहुवरसिपः वाल्स्युगुल्मसंवर्गम्।। १।।

विश्वाता वननगरीः तथा हावनीः
स्थाने पुरुषविनिजनस्तथा च मेहः।

अध्वास्यः करणविहिषु मध्यमानाः
मेतेनु प्रतिवसानं न विचित्रेत सः।। २।।

अक्षांशालितपत्तनाङ्गहीनानाः

संह्यात्तबनवपश्चपुष्कराध्यः।।

अष्टाख्मिशिरीक्रियानहीनसंध्येः
शब्दांशुपहुँतयोजनानि" कोथि:।। ३।।

करणाः: सवगितपत्तनान्तराध्या"

तिर्यकः जनपदभापातः" जगत्यामम।।

तत्तत्त्वंरिवपरं पदनिः केचि--

दध्वानं प्रहर्णितस्य बेदितारः।। ४।।

अध्वानं गणितविदी भटस्य शिश्याः"

स्थूलविचारप्रसिद्धने सम्यगाः।।

अक्षादेशिं च विद्येयोपपितिः"

बक्तवतात् श्रीतिपरिश्रेष्ठेन्द्रिति" सम्:।। ५।।

"बाणाटो A, B. "तत्तातपणि A, B. "लक्ष्मीविह गुल्म" A, B. "From पाणाटो to वाल्स्युगुल्मसंवर्गम् is missing from C. "परनगर C. "तथा हावनि B; तपानी च। निपावश: A; निपावश: B; अध्वास्य C. "स्वाक्षाराणिधितिलंगान्तरहीनानाः A, B. "चन्द्रांशो A, B. "सवगितपत्तनान्तर

रुखः A; सवगितपत्तनान्तर B; सवगितपत्तनान्तर च C. "जनपदभापातः B. "गणितय बेदितारस्य A; गणितय बेदितारस्य B. "शिश्याः C. "विद्येयोपपिति B; विद्येयोपपिति C. "बक्तवतात् श्रीतिपरिश्रेष्ठेन्द्रिति C.


In MSS A and B the last two lines read as follows: लम्बेनाह्य भूमे: सकलमुग्रण्णैः वृत्तसत्वखं वर्तीभि-
हृत्वा” देशान्तराधिकाराचारसहृदे योजनांग्रं वदनिः। ।१०।।

इति महाभास्करीये द्वितीयोऽद्यायः।
तृतीयोऽध्यायः

अश्लि: समस्तवेगम्यः धारात्मकः

ृतृत लिबेत् स्फूटतरं खजु कर्त्तेन ।
सुभृष्टिधयरमवलम्बकसचिवायस्त

"श्रीतात्जीवोऽसमस्वसृतसुतमेः: स्त्रात् ॥ १ ॥
छायाप्रवेशार्थिनितज्ञानकुवलयाः मीनमालिकेदृ व्यवस्थाम् ॥
"सद्यक्षणस्वसृतसृत सृतं सृतं यायोगरं श्रद्धानि: ॥ २ ॥
बिन्दुभित्त्रेवविवक् एवकल्याणः
संशिवेष्टितारिकेवाक्षरः।

सूर्योऽस्मस्मप्रयत्तयोः

योगात् कुलबुदायोविचित् ॥ ३ ॥

तुष्टायाकृतियोगस्य सूत्समाहृत्तांनौपि:।
बिष्कम्भायें स्तव्वृत्तस्य छायाकर्मणि सर्वदा ॥ ४ ॥
छायाहुतं निभवत: "गुणप्रतान्त"
हुन्वा नरेण च पूण्यविभेददेन।

अत्साहलम्बकगुष्णीय विनुचक्रप्रसिद्धि

छायानाम च विपुलावपरस्तुः ॥ ५ ॥

इष्टव्योऽमुतरत्रमुर्ज्ञातस्तीक्षुरुणाः सदा संहरैद्
व्यासार्त्थम भवेदप्रकारमुण्यसत्तालिकस्तुक्तम्।

बिष्कम्भायेंकृतेविवेशोऽध्यात्मः ॥ पदः सुव्यासखण्डः विनु: 
स्तव्वेष्ट्वेष्टिक्तत्तिः पदः ॥ प्रविण्डप्रज्ञानम् जीवा द्रष्टि:।"॥ ६ ॥

1 समस्तवेगम्य: A, B.
2 अत्साहलम्बकगुष्णीय: A; अत्साहलम्बक: B.
3 जाला: C.
4 समस्तवेगम्य: छायाप्रवेशार्थिनितज्ञानकुवलयाः C.
5 तुष्टायाकृतियोगस्य सूत्समाहृत्तांनौ: A; तुष्टायाकृतियोगस्य सूत्समाहृत्तां C.
6 छायाहुतं निभवत: "गुणप्रतान्त"
7 हुन्वा नरेण च पूण्यविभेददेन।
8 अत्साहलम्बक: A; अत्साहलम्बकगुष्णीय: B.
9 इष्टव्योऽमुतरत्रमुर्ज्ञातस्तीक्षुरुणाः सदा संहरैद्
10 व्यासार्त्थम: A; व्यासार्त्थम: B.
11 स्तव्वेष्ट्वेष्टिक्तत्ति: A, B; पदावर्त चुव्यासखण्डः A; पदावर्त चुव्यासखण्डः B.
12 पद द्वार्तितक्तत्ति: C.
व्यासवण्डगुणिते खिलेक्षण
संहरेद् दिवसजीववा । पुनः ।
कार्तिकं च यदवान्तमर्त तु
प्रोच्येव चरदलं सतां वरेः ॥ १७ ॥
जिना दशकाना यस्मर्नभावलिनोः
निशाकरास्थो गुणिता: पलाइङ्गुले ॥
हुसुक्तचुर्ध: क्रियाशो-नरात्मजा
भरवन्त निष्क्षालबा: चरोद्वृष्टः ॥ १८ ॥
शशिकृतश्वरामेणाहता राशिजीवा:
स्वकदनसगुणांशोचिता: कार्तिताश्र्वः ॥
Pतिसमतिरिक्ता: पूर्वाचापारजाहे-१३
वियुद्युदयाश्रिस्मणिव्यः क्रियाहः ॥ ९ ॥
खण्डतस्तशाला हृणु: पञ्चरसाधिरूपः
वियुशिक्षिनव्यक्षाते च दृष्टा विखिरे: ॥
चरदलपरिहीना योजिता व्युक्तमेण
प्रतिवियवसमुखस्तुत्रया भेष्पङ्गः ॥ १० ॥
अपामपलभागा ॥ भेष्माकादिगोले
रत्नसहितस्तड्ध्याय मध्यसुयावनः ॥
अवनितलवहीन: प्रोक्तिश्रवचाद-
स्तवनितलवीचा साप्रभा नेतरा ॥ ११ ॥
धितिजाबुल्लसमासो विश्लेषो बोजरेतरे गोले ।
लाब्धनित्रित्वायतः शाकुदिनमधियगमे ॥ १२ ॥

1. व्यासवण्डगुणिता A, B । संहरेद् बुद्वली A; संहरेद्वली B। 2. कार्तिकं A, B । पर्रलं C। 3. हृदस्तमर्नाय A, B; यम् । शलाणो C। 4. वलायस्तो गुणितान्त बलाङ्गुले A; नवादिस्तुगुणिता बलाङ्गुले B। 5. वलोदनभा A, B; पलाद्वृष्टा C। 6. Paramesvara quotes the following reading of this verse in his Siddhānta-dīpikā:

वमुविदशा गुणस्तमर्नाय नवाद्वशब्धिहार: पलाङ्गुले: ॥
हुसुक्तचुर्ध: क्रियागोमनाजान्तरायसः स्तु: कमस्तु चार्तिकं: ॥

छाया समभिनीतसंतते।
काण्डोभितकतरं यदा पलम्।
तद्रशः स्फुटवर्धपरं—
स्तम्भरिऱधिरपि चोतरे तदा। ॥१७॥
छायाया याम्यकांठायामक्रमावधुंता २ नति: स्फूटा।
जायन्तेजकमा भागा ४ भासवतोजसक्निपथ्ये। ॥१८॥
अक्ष्टोधिततरं यदा नति:
पात्यते पलमतस्तदा सदां। ॥
शिष्यते समभणुः ५ स्फूटे ततो
भास्कर्यिपि खलु याम्यगोलः। ॥१९॥
तदमुषुपन मुणितां तिरासिजम्
ज्यामपकम्युपणेन ६ संहरेत्।
लब्धचापणिते पदक्मादूः।
भास्कर्स्त्रकस्यपणवारिकः। ॥१६॥
उत्तरे संयुतः ३३ सूर्य विश्वेषो दक्षिणे स्मृतं।
अपक्रम्भनास्तानाः ३८ छायाया ७ च पलं भवेत्। ॥१७॥
दक्षिणोत्तरगते विबलति
प्राणराष्ट्रिकस्यादृ धनक्षयो। ॥
स्वाक्षरः ५ वर्दलं सदा ततो।
जीवनावस मुणितं दिवागुणम्। ॥१८॥
संहरेत् स्वभवनस्य ३८ जीवना
तत्र लब्धविचये विस्मृणम्। ॥

१ समभिननसंतते: A, B; समभिनीतसंतते: C.
२ लब्धु A, B. ३ तदभिद B; तल्कर C.
४ क्षयव्या C. ५ This hemistic is missing from B. ६ भोगो A; भागो B.
७ अपक्रम्भनास्तानाः जायन्ते दक्षिणापथ्ये C.
८ पक्षवे वलमतस्तदा सदा A, B. ९ तेधमधु: A; तेवमधु: C.
१० व्योमक्रमयुपणेन C. ११ लब्धचापमुणिते स्फूटे
तत: A, B. १२ योजयेतु C. १३ अपक्रम्भनास्तानाः A, B; अपक्रम्भनास्तानाः C.
१४ छायाया C. १५ प्राणराष्ट्रिकस्यादृ धनक्षयो A, B; प्राणराष्ट्रिकस्यादृधमक्षयो C.
१६ साक्षर A, B. १७ सलो A, B. १८ विस्मृणम् A, B, C.
व्यत्ययं चरदलस्य तत्कुषः
स्वालम्बकलं हरेतु पुनः ॥१५॥

व्यासखण्डनित्येण लघुते
श्रव्याक्रृतयोगासामुद्राः।
व्यासतत्कृतिविशेषजी पदः
कथाते सकुटरा प्रभा सदा ॥२०॥

आदित्यलग्नविवराषणेन हुवः
तत्कालमध्यपरिनिर्मितस्यलंका
विषक-मभेदयुजितः स्फुटशाकृतकः
स्वट्टोलभेदविविधेण प्रभा स्यात् ॥२१॥

रविकृष्णां याम्यायां न्यात्मकेऽविशेष्योपपदमः।
तत्कालमध्य गोलजैलमभकः कथितः ॥२२॥

प्राणेश्वरे रेपृतिविहीनथातीरणं
तान्यायविययकः ततस्य बांस्यः।

शुभयासनमध्यकरस्तताराविवेदितः
छेदिवर्ततंतकृतः: फलस्य शाक्कुः ॥२३॥।

tतान्यायविययकः।। युज्याधिपतेन शाक्कुः हुवः।

वियुत्तकणस्य यज्ञा चेडः।। फलं शाक्कः ॥२४॥।

इत्यादियम्यावराषणः।। ज्ञानः शेषजीवा।

प्राचक्कलभ्यं कवित्सरणं यथः।। हितवः शाक्कः।। स्थवर्मणः ॥२५॥।

शर्मं शाक्ककर्ष्यं कार्यं व्यस्तनं कर्मणा।

दिनस्यः।। क्षयबृद्धियः रात्री व्यस्तनं ते यतः ॥२६॥।

इत्यं ज्ञातविशेशां भक्तं सकल्पाणहं।। संहरेलस्यमेवेन

प्राते भेयायदीर्मकः।। नित्यायगुणकला:।। शोधये दृष्टिविशेषः।।

"समुद्रवं A, B. "विषयेऽपि A, B; "विशेषकं C. "हि सा A, B. "विषादमभेदरहिता A, B. "स्फुटशाकृतकः A. "वा B. "इत्यविक्ष्यामद्यव्यात्मकोऽक्ष्योत्तरस्यस्युपमेष्य A, B; रविकृष्णामयायांयात्मकोऽविशेष्योपपदम् C. "प्राणेश्वरे रेपृतिविहीनथातीरणं B. "ताण्यायविययकं गुणम् B. "ताण्यायविययकं A, B. "चेडः A, B, C. "इत्यादियम्यावराषणः A, B; इत्यादियम्यावराषणः C. "कवित्सरणं यथः C. "शाक्कः A; शाक्क B. "अभास्तु C. "सकल्पाणहं A, B. "मेघा गोले C."
योज्यते तत: समेत त्रिगुणगण्यत् संहृत्रेषोपरि
ध्रुवासार्यो चापे स्थचरदलव्यवस्थेनामुरारिष्ठः। ॥ २७॥

अहं: शेषो गतो वा रस-खस्सुहोऽनादिकादः प्रदिष्टः
विज्ञावर्गः वा स्वामिनितनरः भाज्येद्व चातजेन्।
ध्रुवासार्थीकोष्टग्: स्थचरदलगुणे पूर्ववत्कलिपितस्य
चापे प्राणाश्चराय: पुराणी विचिन्ना व्यवस्थेनान्तुरारिष्ठः। ॥ २८॥

अध्यक्षः श्रद्धुकुभूयो व्यासव्यायः
श्रद्धुकुमुदलापो वा पूर्ववचारिकाविचि:। ॥ २९॥

सूर्यागतसमस्थतः तद्यथीतास्वा हुताः।
राष्ट्रायोऽकावीरा लब्धा रविगतासवः। ॥ ३०॥

इष्टासुभो विशेषवैतान् रवी चापायगः क्रियेत्।
राष्ट्राध्यानस्तोपायस्य देवा भानी च राणस्य। ॥ ३१॥

शेषः विश्वस्मस्मस्मित्तोराध्यायसुभीतह तमः।
लक्ष्मणादिसंगुक्तत्मित्तकालोदयं विदः। ॥ ३२॥

पूर्ववस्तः स्त्राचार्यस्मतलम् विक्रीयेत्।
उदयस्ववास्तमयते राष्ट्रो यतः। ॥ ३३॥

उदयस्य ग्यते "भान: स्वोदयेन हुता हुताः।
विज्ञाता प्राणलोच्य: स्पाल्लवः लक्षणायस्य: पुत्रः। ॥ ३४॥
आहारणी यावदर्शस्य राष्ट्रिसुभीतासवः।
जानन्ते पुरुस्कृतः गलन्त्वाणासुभीतह:। ॥ ३५॥

प्राणा दिवसास्वविविधेशः शुभविविजित:।
षट्याः शूरयोधिपि न लब्धा चतिविद्धिकासवः। ॥ ३६॥

स्फुटरविभुजनिन्दन- याॅ परां कान्तिजीवां
हरतु समवलम्ब्याकलापेन भूयः।
स्फुटरविभसराया सा यदाश्वांशिहीना
रविरवि यदि गोले चोतरे लम्बकहनामेन।।३७॥
अक्षया हरदू भूयः शाकुः स्थात् सम्मण्डलेन।
तद्यथावस्तुत्यथयथोद्विशलेष्य तस्मां व भास्मां ॥३।३॥
मानोयुजामामित्यं परमापमेन।
बुधवासेद्भविततथाखलसिनिषः।
अक्षयाक्षयकृतिवदृश्यैतरित्रिमोक्षी।
मूलस्थ काण्डसवो गगनावधवो।।३९॥
व्यासर्थितातिदितपु: सममण्डलस्य
दृष्यावधवावः दिवसविश्वस्तरेद्विभक्ताः।
लक्षस्य कामुकविभेरसुनारङ्कक्षाः।
भास्करक्ष्मय्यवित्यवपभवं भविन्तं।।४०॥
छायामिनीसममण्डलद्विकृतिनः-
मक्षस्य 'यद्यृग्गुमुपाहर नित्यमेव।
सर्वप्रवेञ्य' समवात्त्वनुविवस्वानूः।
युक्तयाव विराजितंत्र भटप्रणीतः।।४१॥
अर्पाशाह्वैव छायाः च वशेष्टकालिकाः कुलाः।
अगस्त्यस्य योगवस्तुवाचासायन्यविवर्म्।।४२॥
तेन छुष्णां छाया भक्तवा तदृश्यमुपनेन यस्लधाम्।
कुलदिरविवाहकेत्तादू दिव्यविदर्शं नित्यात्वाध्यम्।।४३॥

'स्फुटरविभुजनिन्दन याॅ A; स्फुटरविभुजनिन्दनाय B. 'लम्बकहना: A, B.
'शाकुकयासममण्डलेन A, B. 'तद्यथावस्तुत्यथयथोद्विशलेष्येष्य यस्मां A, B; तद्यथावस्तुत्यथयथ
स्वस्तिविश्लेषः यस्मां A, B; तद्यथावस्तुत्यथयथाभास्मां A, B; तद्यथावस्तुत्यथाभास्मां A, B.
"यथा प्रकृति" B. 'दृश्यावधवा A,B; 'दृश्या".. C.
'काण्डसवेद्भविततथाखलसिनिषः: A, B. 'यथा विन्दमेन य, A, B.
'सर्वप्रवेञ्य' समवात्त्वनुविवस्वानूः A, B. 'युक्तयाव विराजितंत्र भटप्रणीतः।।४१॥
'योगवस्तुवाचासायन्यविवर्म्।।४२॥
'यथा प्रकृति" B. 'दृश्यावधवा A,B; 'दृश्या".. C.
तन्मत्स्यभिद्वृत्तेः प्रागपरिदिशोऽऽ्रसायंते दूरसः।
चायाप्रमाणप्रयत्नं तिर्यक्केनैवादिनं नेयसः। ॥४८॥
बिन्दुमयस्तः तिर्यं पूर्वपरयोद्विषयायोऽगमः।
मध्यच्छायाशिरसमेव बिन्दुमयस्तः। ॥४५॥
यो वा स्यादविनितिदिनिविभागकेनेऽसः
दिक्षायाप्रमाणविभिः प्रकर्तुकामः।
तस्याशाौस्त्वलिङ्कोऽरुक्तनेमः।
नः च्याया त्वाज्जति रथ्या तथा प्रवक्षे। ॥४६॥
इष्टेन्तस्तः कृत्वा दृग्याः श्रक्कसः तथा चः श्रक्कसः।
विशेषोऽवामुग्नितवाःः करणेषर दृग्याः। ॥४७॥
तत्रतत्तिविखलेषपरं दृग्याकरणस्यः कथयते कोटि:।
च्यायाने कोठे मुऽजुः दृग्यामवते तयोमनि। ॥४८॥
श्रक्कस्त्वक्कसमवपुष्टः वजवोः सुध्रकोटिमानस्येव।
बंशालकास्तत्तति: कोणेः कृत्वश्रक्कसस्वारसः। ॥४९॥
चतुरं चुतिक्ष्यं विभूषा वा कारयेत् स्पुः यन्त्रसः। ॥५०॥
विन्यस्तदृः रः भ्रमणेच्छायाकरणान्तु गावत्। ॥५१॥
आशा भुजकोटिमाः च्छायाकरणायमेव सादृः।
मध्यच्छायातिवरसमेव ज्ञायोऽविन्दुस्ततीयोऽज्ञः। ॥५२॥
बिन्दुमयसः सकलस्य विरोगवाहि
संलिप्तेऽस शफरिकान्वितेऽनेः वृत्तमः।

"तन्मध्यभवितुः A, B; तन्मध्ये भेदसूः C. "ज्ञेयम् A, B. "****हविन्दुः A,B; बिन्दुः C. "हविन्दुः तिर्यग्यस्यतः A; हविन्दुः तिर्यग्यस्यतः B. "In MSS A and B, verse 45 occurs after verse 47. "स्यादविनितिदिनिविभागकेनेऽसः A; स्यादविनितिदिनिविभागकेनेऽसः B. "** missing from B. "वृत्तमेः A, B; तस्या: स्पुः तिर्यलिङ्कोऽरुक्तुः C. "य A, B. "च वः C. "इष्टेन्तस्तः A; इष्टेन्तस्तः B. "ед्याः A, B. "च वः C. "विशेषोऽवामुः A, B. "विशेषोऽवामुः C. "तत्रतत्तिविखलेषपरं A; तत्रतत्तिविखलेषपरं B. "श्रक्कस्त्वक्कसमवपुष्टः A, B; श्रक्कस्त्वक्कसमवपुष्टः B. "मान missing from A, B. "चतुरं चुतिक्ष्यं विभूषा A; चतुरं चुतिक्ष्यं विभूषा B; चतुरं चुतिक्ष्यं विभूषा C. "य A, B. "आशा भुजकोटिमाः A, B. "विन्दुः तिर्यग्यस्यतः A, B. "विन्दुः तिर्यग्यस्य C. "सफरिकान्वितेऽनेः A, B; शफरिकान्वितेऽनेः C."
तन्मण्डलार्गिश्विविविविशिशविषयकं
झयं प्रयाति वर्णाव्रुवं हि मन्त्रश्वद् ॥ १५॥
इष्टकावितितितिजार्गिश्विविविविशिशविषयकेऽ
विलिजा ज्ञात अवध्यता सुर्याङ्रुवताः पलस्येण गुणः ॥ १५ ॥
अशक्तो वाहतः शाङ्कुरिण्टकालसुनाबः ।
भाजितो लम्बकेनाथ शाङ्क्वथं निर्यंदक्षिणम् ॥ १६॥
शाङ्क्वथं द्वारावन्यस्तं स्वेष्टशाङ्कुञ्जन्नो फलम्।
झयं वैपुण्वताः जेनां विस्तरणप्पि कथयते ॥ १७॥
श्रीवासमां भगवानम्भविविविशिशविषयः ।
कुर्यातु स्त्रेषु समतलां कुलदिविभागान्।
तस्या जलेश्वरिश्विविविविशिशविषयसंकेतस्य- ।
विवाहितश्च परिविश्वजनानाकुलालम् ॥ १८॥
पूर्ववेश्वरवेश्वरवेश्वर रविवेश्वर चाल्टरम्।
अर्कावासायणिनयें परिबोहः मागलक्षणेते ॥ १९॥
अर्कावासायणं भवेश्वरं तामसित्याविवेश्वरजः ।
लिप्तो शाङ्क्वसाज्जिवाय दश्ये चोतरेश्वया ॥ २०॥
दसिद्धार्थ्विनविन्ती ज्ञाता यदां भवति भास्वतः।
नतिज्ञाराहिरकेषु शाङ्क्वथं कथयते तदा ॥ २१॥
विष्ट तेन विपुवप्रभां सतीं ।
पूर्ववेश्वर पलस्यकै ।
वेदित्वाविविविशिशविषयां
नापकारिष्ठविषयम् तस्यः ॥ २२॥
षद्गुणास्तु च चित्का लवास्तु तैः ।
पूर्ववेश्वरिश्विविविशिशविषय स्विष्टेत्यः ॥ ॥

¹ मस्तके यव्यायः व, व; मस्तके यज्ञायः न; फणिनि वाहिनु व. ² समासपद-मुप्याये अकेश्वरः व, व; वज्ञायः व; इष्टकावाहः च; इष्टकावाहः व. ³ वेश्वरसमां व, व; श्रीवासं समां च; स्यलानमात्र राक्षस-विविशिशवागम् च; स्यलानमात्र राक्षस-विविशिशवागम् च. ⁴ विवाहि अ, अ, अ, अ. ⁵ परिते अ, अ, अ; विवेश्वर अ, अ. ⁶ लिप्ता अ; वेदित्वाविविशिशविषयां अ, अ; सती अ, अ. ⁷ पूर्ववेश्वर चलनमको च; पूर्ववेश्वर चलनमको च. ⁸ तत्पर: अ, अ; तद्गुणास्तु अ, अ; श्रीवासमाः अ, अ. ⁹ अ: अ, अ; अ: अ.
उच्चते धनमणि क्रमण तान्त्रिकाः।
ज्ञातचारिनाः सुब्रह्मण्य:। ॥६॥
एवं नक्षत्रालंकारं गहन्तः स्त्रामिषः ॥६॥
सावित्र प्रभवेण्यं युवः सब्रवं तवदा ॥६॥
अप्नो भाषाः भिवेये, पदं स्वरुपः सुविषयः।
हि दिवशं सिद्धने, हि च विधयस्य स्थिरः। ॥६॥
अप्नो सार्थस्ित्रस्त्रपते, वेदा: वैमोकरणः।
पञ्चचक्रं कुलाराषोऽद्विनोधस्तावः। ॥६॥
एकोज्ञाज्ञां श्रवं धारणं स्थाप्ये, भूतेष्वरेष्वरः।
मूयेश्वरद्विनोधस्त्रकं तु पञ्चचक्रं द्विशचितः। ॥६॥
योगभागः। क्रमणे तोञ्च्यास्ते शिष्यभावणिः।
उदयालकुसुतानि दक्षणे पञ्चविवधा। ॥६॥
उद्धरसार्थस्यानि दक्षणे पञ्चविवधा।
उद्योगकक्ष्णि ते सीकादक्षणे सप्तं चालिनी। ॥६॥
सत्तानार्थरागा याम्ये सार्थस्यार्थस्याः।
अंवध्यौद्वल विभागः। स्वरास्ते सत्तभागः। ॥६॥
उद्धर दिशत् कृति: पणां याम्ये लिप्तार्थस्थिरः।
उद्धरिणा दिविष्ये। च विहाय: कौर्याः स्थपरः। ॥६॥
विद्येपावः: क्रमेणकत्र बोद्ध्वास्ते शिष्यभावणिः।
योगभागसमा: सर्वं द्वम्यन्ते योगजः ग्रहः। ॥७॥

¹ धनमणि A, B; अतनमणि C. ² क्रमेण...जातचा...सिद्धवे: समा C. ³ स्व: एकोज्ञा A, B. ⁴ लिप्तार्थस्थिर A, B, C. ⁵ सार्थस्यार्थस्याः A, B; सार्थस्ित्रस्त्रपते C. ⁶ ज्ञातचारिनाः परे A, B. ⁷ हि विनायकः A; हि विनायकः B. ⁸ एकोज्ञाज्ञान्तराधस्याः A, C. ⁹ चापूर्वोत्स्पद्यन्तुम A, B. ¹⁰ मूयेश्वरशाला: क्रमेण A, B; मूयेश्वरद्विनोधस्त्रकं C. ¹¹ पञ्चचक्रं द्विशचितः A; पञ्चचक्रं द्विशचितः B; अशिवाधारण: C. ¹² योगभागः B; योगभागः C. ¹³ बोद्ध्वास्तेश्चिनाविणिः A; बोद्ध्वास्तेश्चिनाविणिः B. ¹⁴ दक्षणे वाणायनम् A; दक्षणे वाणायनम् च दिप्पवः B. ¹⁵ उद्धरसार्थस्यानि दक्षणे पञ्चविवधा A; उद्धरसार्थस्यानि दक्षणे पञ्चविवधा B; उद्धरसार्थस्यानि दक्षणे पञ्चविवधा C. ¹⁶ उपलस्य ते A; उपलस्य B; उद्धरस्य C. ¹⁷ सप्ताशिर: दुस्तभावः A, B. ¹⁸ अद्ध्वास्तेश्चिनाविणिः A; अद्ध्वास्तेश्चिनाविणिः B. ¹⁹ उद्धरिणा दिविष्ये C. ²⁰ कौर्याः तवरः A, B. ²¹ शिष्यभावणिः C.
विक्षेपाशीर्तयोः साध्यमन्त्रं प्रहृतार्योः।
उच्च्यन्ते हस्तितिस्ताताभिहंतीनुवृद्धिस्तिंगायाः।॥७९॥
श्रेष्ठः शर्मं छन्दोः लघुचितवर्गः तारकाम्।
नवत्त्वा सारंया चित्रां द्विशत्त्वया एकतः तारकाम्।॥७२॥
शतेन चार्ध्युक्तेन् भृत्र शतमिष्टिजस्ते।
नवत्त्वा इत्यौपद्राग्नं पीणं विक्रिष्टितवर्जितम्।॥७३॥
उत्तरेण शतेन प्रष्टीं बुङ्गावसेन उच्च्यते।
उत्तरां परमां गत्वा मध्यमद्धस्थायतारकाम्।॥७४॥
यष्टियुक्तकलास्तेता ग्रहैनेन भेदने।॥७५(१)॥}

इति महाभाष्यकरिदेये तृतीयोःश्लोकः।

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1. उच्च्यन्ते C.
2. भष्यज्ञ: A, भष्यज्ञ: B.
3. लघुचितवर्गः C.
4. तारकाः A, B.
5. ग्रहेण C.
6. विशत्त्र एकतारकाम् A, B.
7. द्विशत्त्र एकतारकाम् C.
8. चार्ध्युक्तेः A, B.
9. शतमिष्टाजिनिः C.
10. इत्यौपद्राग्नाः A, B.
11. चूतवेद्यं A, B.
12. विक्रिष्टितवर्जित C.
13. शलेनास्ती A, B.
14. बुङ्गावसेन A, B.
15. लघुचितवर्गः A.
16. मध्यमद्धस्थ तारकाः B.
17. उत्तराः... भेद C.

missing from C.
चतुष्कोटिध्वयायः

कत्वा देशान्तरं कर्म रवेशुव्यं विशोधयेत्।

वेषं सुप्रस्य यत्कैव तत्सिन्न राशितिः पद्म।

जीवा: कमोक्तमान्यां तु प्राहाः केन्द्रविद्रोहः।

जीवानां ग्रहणोपायाः कथयते विस्तरण स:।

लिप्तकुल्यं हरेन्यमय्या जीवा लक्षदलः पुनः।

वर्त्तिकाव्यं शेषं मध्यं चौवं विभाजितं।

पुर्वसंस्कृतं युक्तं ज्या: कमेश्वरक्तमेण वा।

स्वपरिप्रक्ष्यहोच्चिं शेषं श्रावणं फलम्।

केन्द्रालपविभागेन श्रावणवधनक्षय:।

देशान्तरक्ते सुर्यं कुतःसनमस्यं सदा।

केन्द्रे कियात्तिः चास्य फलं वाहिकोविधयेत्।

तुलायादेव तत्तवं देवं स्फुतविद्वृक्षणं।

कमोक्तमकलाम्यस्तं मध्यं बाहुफलेन वा।

भृतिदचक्षकलाव्यं पुर्ववत्तालक्षणं।

बाहुकोटी वा कमात्रेन्द्रे कोटिबाहु गतापि।

तयोर्गुणवले प्रायम्बु कान्तिः परिवृत्तिः।

भावो पदे चतुष्कं च व्यासां कोटिसाधनम्।

सत्यं शोधयते चौवं शेष्यो: कोटिका भवेत्।

तद्भावंगोणिष्यं मूलं कर्मः प्रकृतिः।

बाहुकोटिकलिप्यमस्तं कर्म व्यासार्थप्रविशति।

-- शिर्ष: C. । केन्द्र: C. । जीवा: देशान्तरं पद्ममात् missing from C. । जीवाय: A, B. । ग्रहणोपायाः C. । ज्याक्षेपणलक्षणं C. । स्वराप्रतिहातशीताय: भक्तोऽस्म्याध्यानं C. । ध्वनिं चन्द्रवनस्याः A; ध्वनिं एन्द्रवनस्याः B. । देशान्तरक्ते A, C. । केन्द्रालपः कियात्तिः A, B. । केन्द्रकियात्तिः वा फलं वाहिकोविधयेत्।

तुलायादेव तत्तवं देवं स्फुतविद्वृक्षणं।

कमोक्तमकलाम्यस्तं मध्यं बाहुफलेन A, B. ।

भृतिदचक्षकलाव्यं पुर्ववत्तालक्षणं।

बाहुकोटी A, B, C. । कोटिबाहु B, C. ।

प्राचार्यछोंदं वा तद्भावंगोणिष्यं मूलं A, B.
भुजाकोटिफले स्वयं ताम्या कर्णश्च पूर्षवत्।
भूमि: पूर्वफलायस्ते कर्ण विज्ञाविभाज्यते। ॥११॥
एवं पुनः पुनः कुशीकरः: पूर्वोत्ततकर्मणा।
यत्रतुष्यो भवेतकरः पूर्वोबिन्दनास्मुता। ॥१२॥
विभक्तभार्धः मुखत: सूर्यचंदनसोऽस: सदा।
स्वविशेषां कर्णं स्तुतमुखः स्वभवत्वाध्ययते। ॥१३॥
अस्त्यजीवायवः स्थुत्या गुणिता धनुष्या हृता।
स्वपरिध्याहतेजीवः लब्धे हीनाधिके स्थुटे। ॥१४॥
अस्त्यजीवावः खण्डे केन्द्रभोगार्ददीधोधेत्।
तद्भिषोचयः शब्दशेषोऽथाते अवशेषविषे। ततः। ॥१५॥
उच्चभुजुक्तिविहीनः भुस्ते। शीर्षांचुमालिनः।
उलकमुखा कर्मे ग्राहा कर्मज्ञा चोककमिश्यते। ॥१६॥
आकार्तियोऽवलं चुक्तः गुणायोगानुपातः।
तत्त्वने विज्ञानाधि भुस्तितः स्थुटतः महा सा। ॥१७॥
स्वस्तनाश्वतवयोऽद्विस्ते पदार्द्धमोक्षः।
विश्वस्तनाश्वततन्योऽस्मानी अवशेषविषे। ॥१८॥
कोशाया पदवशाब्धः युक्तः वास्तवपुणः।
तद्वर्गावहुवर्गः योगास्त्रयः पदेः। भवेतु। ॥१९॥
कर्णान्यान्यस्तीतः ह्वतं विभक्तभार्धः नभये।
पूर्वकोटिया धनन्त: स्वायास्तु कर्णः। समो भवेतु। ॥२०॥
भुजाज्याभिन्हता निघासा थोरणाप्र्दश्याः। कर्णान्यान्यस्तु: कमादू।
केन्द्रालसेविभागेन धनं श्रोत्रेये प्रक्तपेत्। ॥२१॥

1 स्वायास्त्रय भुजाज्याभिन्हता निघासा थोरणाप्र्दश्याः ।
2 कर्णः A, B. 3 याबलुत्या भवेतसंह्या कर्णेश्च विभिन्नामुर्ता।
3 Missing from C. 4 स्वपरिध्याहतास्त्रया लब्धा हीनाधिका स्तुता।
5 केन्द्रालसेविभागेन धनं श्रोत्रेये। A, B. 6 वदेष्टवरुणस्य: शेषं A, B; तद्भिषोध्यमिश्रयः। C.
7 पायते विषमें A, B, C. 8 भक्ते A, B. 9 वेक्ते A, B. 10 युक्ता। C. 11 तत्त्वादेहो C;
12 विन्हीनाप्रता A, B. 13 हस्तनान्यान्यान्यन्यान्योऽस्मात्विषायो: A; हस्तनान्यान्यान्यन्यान्योऽस्मात्विषायो: B.
14 भानान्त: A, B. 15 तद्वर्गावहुवर्गः य: कर्णः पदेः। C.
16 पूर्वकोट्या धनन्त: A, B; पूर्वकोट्यायन्त C. 17 स्वायास्त्रयः A, B. 18 भुजाज्याभिन्हता निघासा B; भुजाज्याभिन्हता निघासा C.
लवेव केवल पूर्व चक्रां तेन वाचितम्।
चक्रां तत्त्व चक्रां च संबन्धं स स्फुटो रविः।
प्रतिमण्डलसतिद्विरेष्या सम्यकः प्रकटिता।
स्वात्मेऽ फलं च सर्वं चुम्चुअवत्ते प्रतिमण्डलम्।
स्फुटस्ववेशमध्यज्ञकिर्मेश्वात्संगुणम।
भूकिर्तचक्रालावपातं पूर्वकषे मुष्मातरम्।

बयोदसहुलाौ जीवा निर्युक्तस्य विद्वस्तः।
हवार्तिता हुता कावितः प्रकोष्ठस्तु पूर्ववत्।
चरमप्राणुहुलाौ भूकितरहोराजायामाजिता।
उदयास्तमयों। बुद्धि। क्षेपास्तरगे रवि।
व्यत्यो दक्षिणे भानाक्षेपायनमुपात्तः।
फलं च तद्यास्वाहिदिन्ते क्षेपः क्रोधनमेव वा।
उदयवरायर्मुयुः पादोऽहोराजस्वम्भवः।
दिनाय दक्षिणे हैनं हृदयं हृदयपयान्तु।
पूर्ववालहुला भूकितर्म्या चक्राङ्कलाहुला।
भास्त्रस्य वशाल्वः क्षेपः बुद्धिवा विनिसाक्तः।
शंयं विवस्त्ता तृत्यं कर्म चचर्त्र्य कृतितम्।
भास्त्रद्रुजालेवौ शेषाणां तु प्रक्षत्वेवः।
स्फुटिर्मोऽस्। श्री चेवो विनातिमे। बुद्धिभूतः।
तिथिस्तंत्र लक्यस्ते क्षेपं ष्ट्रायः।
समाहतम्।
विनुवादुः भूकितिविशेषेण घटीविशेषिकासः।
विरेणियोऽ गतो वाचि निदिष्टो भास्त्ररोद्वात।
तिथिमें हारेवधानिन करानिन वचादितः।
विद्यापिरा सिते पश्च सहस्राण्यसिते बिडुः।।13।।
लिपोक्रतो ग्रहश्चरः: शतरुण्डामिश्रयते।।
ज्योतिषं निषयो यातो तु भूक्षया शेषादू घटोयितः।।13।।
सूत्तनुयोगे चक्राधे व्यतीपातीय वैवृत्तः।
चक्रे च मैत्रपयङ्गे विशेषं: सार्वमस्तकः।।13।।
नानानुषे व्यतीपातसुत्वायः समयोऽस्तयोऽ।
उद्येस्तस्तृण चक्राधे विशेषमस्तविधिकोन्हः।।13।।
तिम्माङ्के नेयत्रज्ञेयाः: कमक्षमाहरापिः।
भुजाकोटादिसिद्धवच विशेषोऽज्ञविधायते।।13।।
स्ववृत्तान्तर्गुणां ज्ञां पदयोरोजयुगयोऽ।
कमक्षमाः सु तिमोविधितः परिधी परिक्षये।।13।।
क्ष्योशिकाचूँचितीहि '' परिधी: स्मात स्फुटो मतः।।
तेनाहतेषकेन्द्रज्ञाः छितवासीयः'' फले बिडुः।।13।।
स्वमन्दकेन्द्रसंप्रात्तिकान्तर्पर्वस्यियते''।
पदकामवः भानो: स्वमध्ये तत्त्तवीये।।14।।
श्रीग्रेषकेन्द्रस्पर्शस्तथ विष्कम्बार्षविभयज्यते''।
स्वकृत्तान्तनाषकारारां कार्यं तुस्मितिविययातुः।।14।।
तस्मात्स्तत्षकेन्द्रसमुस्त्रमहति स्वमध्ये म।
एवं ब्रह्माक्षीवानाः'' विशेषः: स्फुटस्मित्याः।।14।।

' ब्रह्म: C. ' शरेरुण्डामिश्रयते A, B; शकःरुण्डामिश्रयते C. ' शेयादूटी B; बिडु: A; भेषा पृः B; शेयादूटी B; C. ' अथूरुम C. ' चक्रे मैत्र A, B, C. ' नानापन सार्वमस्त: A, B, C. ' नानात्मा व्यतीपाते सुर्योपस्योर्षोलेशस्तस्मात्तर्क C. ' विशेषमस्तविधिकोन्हः A; विशेषमस्तविधिकोन्हः B. ' तिम्मागु: केन्द्रकेन्द्रज्ञेयाः A, B; तिम्माङ्केन्द्रकेन्द्रज्ञेयाः C. ' त्वृत्तान्त त्र्वृत्तान्त A, B; त्वृत्तान्त त्र्वृत्तान्त C. ' कमक्षमाहस्यियः A; कमक्षमाहस्यियः B. ' श्वेषयित्वृत्तान्त Hोत्रे A; श्वेषयित्वृत्तान्त Hोत्रे B; श्वेषयित्वृत्तान्त Hोत्रे C. ' तस्मात्स्तत्षकेन्द्रसमुस्त्रमहति A, B; तस्मात्स्तत्षकेन्द्रसमुस्त्रमहति B. ' तस्मात्स्तत्षकेन्द्रसमुस्त्रमहति A, B; तस्मात्स्तत्षकेन्द्रसमुस्त्रमहति C. ' तस्मात्स्तत् भूमाक्षीवानाः A, B.
तद्युत्तिलीकलोप्तसर्वप्रनालापेन वस्मतः।
स्तुत्मद्ध्यः स्तुतोऽशः रोषयोज्यते विधिः ॥४१॥
शीघ्रःग्रामायायायायायेऽध्यौतिहीनः विधयतात्।
मन्द्रोचचः स्तुत्मद्ध्यसः कर्ता शीघ्रारात् स्तुतो विधुः ॥४२॥
शनिधिन्द्रकर्मिणि योज्यमय विधयतात्।
मन्द्रोचचः पूर्ववक्तुवर्च्छेडः गृहविवाहस्तिष्ठायते ॥४३॥
तदेव केवलः शोषयः चक्रायुःचिष्ठा तच्चालात्।
चक्रार्धसंगुष्ठचारः चक्रार्धसंगुष्ठचारः च शष्यवतः ॥४४॥
स्तुत्तुत्तमुर्गाः निर्भयः हुल्लावशीत्या स्वकोरितः।
त्यतः पदेषु पुरुषव वा कर्णः प्राम्बवृत्त प्रसाध्ये ॥४५॥
मन्द्रोचचः सदाध्यविशेषपार्थसमविश्वः।
मन्द्रोचचः देविके हीने रहितो मध्यमो यथः ॥४६॥
स शीघ्रःचालनः साध्यः सिद्ध्योर्तन्तरालमः।
अधीरिक्ष्यः सकृतिः पूर्ववत् परिवल्येत् ॥४७॥
एवं कृतसं भूयोज्मि मन्द्रोच्चिदिः समाचरेत्।
मन्द्रोच्चिदिः तथायें विशेषोऽधिबिधास्यै। ॥४८॥
दिक्षिदमन्द्रोच्चिदिः दिक्षिदमन्द्रोच्चिदिः यद्वतरमः।
प्राम्बन्धः चाल्यमें क्रता शीघ्रःसिदिः। ॥४९॥
एवमार्थात्किर्मिज्ञानामधायं ॥४५॥
श्वरोप्यायं सम्पुष्टयेते यो विधिक्रमः। ॥५०॥
शीघ्रःचालकसदाध्यविशेषपार्थसमविश्वः।
मध्यान्नुमीलेकिः हीने मन्द्रोच्च संस्कृतः ॥विधुः ॥५१॥

¹ तद्युत्तिलीकलोप्तसर्वप्रनालापेन A, B.
² स्तुत्मद्ध्यस्तुतद्घुः A, B, C.
³ शीघ्रःग्रामायायायायेऽध्यौतिहीनः A, B.
⁴ मन्द्रोच्चिदिः संख्येऽध्यौतिहीनः A, B, C.
⁵ शीघ्रःसुतुपुः C.
⁶ शीघ्रःचालनः स्तुतिः A, B.
⁷ तदेव केवलः शोषयः पूर्ववत् परिवल्येत्.
⁸ मन्द्रोच्चिदिः समाचरेत्.
⁹ शीघ्रःसुतुपुः A, B.
¹⁰ चक्रार्धसंगुष्ठचारः চক্রার্ধসংগুষ্ঠচারঃ B.
वुषभृषौ: पुनःसाध्यं मात्मेवं स्वकर्मणं।

तेन सिद्धी च चलाद्य भूयः स्फूटावेत् प्रकृतिती।

कोटेत्वर्यर्थं शोध्यं न शुध्येद्य व्यत्यस्तदा।

कार्यं: "कर्मोऽसकुमारं: सकुमर्कन्तु: शीर्षज्।"

स्फुटमध्यमान्तरं दलवं मध्यवनं धनं चले कुलव।

दक्षात्वकर्ममेन: विजुभेते तच्छेत्वृत्तिः।

शोभ्रोच्छातू स्फुटस्थारो निक्रियति: शेषे यदा राष्यय-षेषारो यस्व वकाल्यभिमुखः पद्याचारिकस्ते सः। अहो चेतुकुटिलं जहानिः विहागः पत्यानमागावि सः।

लेख्यातिभवचारिणोऽविवर्तः भूतिर्भेदवः क्षित्तिः।

मन्दालस्त्रजीवार्णिं घन्वाकर्षणं स्वनुक्तिं।

भूय: सवृत्तेन हंसतं विभ्जय।

राजा कलामिदस्वातिलाभभि:।

भूवती घनाणं पदवुकिलतोऽथम्।

शोभ्रोच्छामुक्तेत्स्तदपास्य। शेषात् केन्द्रान्यतन्त्रीविविधता।

यदाप्रतम।

बिज्ञावाहां कर्णविभक्तमेंद्र

व्यापेन शीर्षस्व घनविनिर्माणम्।

तमस्मौर्वीकालचायुक्ता।

सर्व स्वनुक्ती घनासने तु।

तस्याविनिर्मकस्य चलोच्छमुक्ते।

जीवाशालेन सर्वमन्फलराशः।

"तुकः A, B. " बुधभृषोऽसकर्मणं missing from B. ""स्फूटावेत् A, B.

शुध्येद्वर्ययान्तरस्य सध्य: A, B. ""सम्मत: सप्तकः: स्वायंत्र: A, B. ""मध्यवनं: धनं च A. वः ""तत्वित्वकर्ममेन: C. ""निपटिताच्छिन्य A, B. ""पद्मितु व: A; पद्मितु व: B; प्रत्याविर्तिको: C. ""सु C. ""स्वप्रातित्वचारिणोऽविवर्तः A, B; नेत्रातिभवचारिणोऽविवर्तः C. ""भूतिर्भेदवः C. ""मन्दालस्त्रजीवार्णिः C. ""वद्युकिलतोऽथम् A, B. ""शोभ्रोच्छामुक्तेत्स्तदपास्य A, B. ""कर्णविभक्तमेंद्र व्यापेन A, B; कर्ण विभक्तमेंद्र व्यापेन C. ""पुषुक्ता A; पुषुक्ता B. ""सर्वस्वमुक्तुस्त्रस्य: स्व।

तस्याविनिपत्त: स्व C. ""चलोच्छमुक्ते जीवाशालेन A, B. ""सर्व-मन्फलद राशि A, B.
एवं प्रहारणा स्फुटभूमितरिण्टा
तस्मात् शुचिकेन श्रीध्राजलयम्
तयोऽविशेषः स्फुटभूमितसध्
बक्षी प्रहोस्माणिते सद्याप्रिष्ठतः। ॥ १७ ॥
एवं सुरेष्यार्किष्ठरायुतानि
भूक्ति: स्फुटातोऽ भूगुणमसुमन्वोऽः।
मन्दोप्यकमन्द्राधि संस्तुतानि
श्रीध्रान्त्यजीवितज्ञानि: गदात्प्रम्। ॥ १८ ॥
तेनेव सर्वेण युद्धोऽ विस्मिनः
भोगः स्फुटस्यं कणितो विशेषः।
इति: प्रहारणा व्यवहारिकी स्वादः
भूक्ति: स्फुटस्यसत्तरा च नित्यम्। ॥ १८ ॥
गनः गन्यायातितिनिषेधसहूऽ रविन्द्रो-
भूक्ति क्रमेनः दिनभूमितिविशेषाभ्यते।
लब्धेनः स्मृतार्थ्यत: शास्तित्मरसमी
जेयो।समी सकलोकविधानहेतु॥। ॥ १८।।

इति महाभारतरीये चतुर्दशथायः।
पद्मसंहितायः
भास्वतो गहणं वाच्यमाचार्यं विमोचनं विनिःशयं।
तस्य चादी विज्ञानीयाः दुपाराः विनिःशयं॥१॥
पद्माष्ट्रमूर्तरस्त्रपेशे वेद: कणों विवेकं त:।
सप्तवंशतरामविधिगुणसंव्यया निशाचः॥२॥
कलाकृत्त्वातः विज्ञाबधविभाजिता।
स्फुटकोणनवाणी तौ सूर्यचन्द्रमोक्षिनः॥३॥
दिशेदायसाः भानोरिस्नोरितिथिःतुच्छायाः।
योज्यस्नरुषं सत्यम् तैवुपपक्षः।॥४॥
विज्ञाबधेनयासी स्फुटकोणनाशिरी।
भवस्ति कलावासाः।॥५॥
नवांश: पद्मभोगस्य शून्यवगः एव च।
स्वरुपविनितास्मिनं तस्मात् स्फुटे॥६॥
सूर्यचन्द्रमोक्षिनः राहुःविस्तर च कथयते।
पद्मकंशत्रम्भोगस्य पोद्धारशी विनिःशिका॥७॥
अधातो मध्यतमवस्य विद्वानं समप्रवक्ष्यते।
निर्धारामुखभवित्वां भाषान्तरविशे:॥८॥
पूर्वात: सूर्यगुक्षस्य गतभागासयो हि ये।
गन्धवानं चापराश: भागानामसव: समृद्धा:॥९॥
मध्यनिध्यतमन्त्राः: शोध्या भागादि: भास्करे।
शोध्या देयश्च भूयोपि निर्धारामुक्ताश्रावो॥१०॥

¹ पद्मचार्तानुग्रहादेस: कणों विवेक: A, B; पद्माष्ट्रमूर्तरस्त्रपेशे वेद: विवेक: C. ² सोस्सदा C. ³ सदमभिमृत्वा: वेपु पद्विनिः B, A. ⁴ कलावासाः A, B; ⁵ शीतागुणेऽस्व: A, B, C. ⁶ युक्ताहि तन्त्र स्फुटे A, B; युक्ताहि तन्त्रस्फुट: C. ⁷ पोद्धारशीनिः B, C. ⁸ गन्धवानं चापराश: B; गन्धवानांग्न्धाश: C. ⁹ मध्यनिध्यतमन्त्र: A; मध्यनिध्यतमन्त्र: B. ¹⁰ भागाश्च A, B; भागाहि C.
राधयः कालतत्त्वज्ञरुपात्तास्मात्म् ।
मध्यलत्वमिदं स्वप्पं श्रीमद्वृट्टकुसुरविदः।।
कांस्यनवेदन्त्वशीरमान्विज्ञानविवेकः प्रकीर्तितः।।
जापनं च स्वदृढःपृथ्विवादिवचनं प्रभोः।।
वाहुज्योदयलग्नश्च परकर्तितवत् हुता ।
लम्बकनेदोदयवापी कथयाणं भास्वतं स्वुदृढः।।
संहितैवाचीनाय जीवा लम्भस्य तारिता ।
तिनिषिस्वमन्दरेभिक्षुपञ्च बिलग्नाः।।
विनिकालानिषिस्वप्पणेऽतुत्यविदः।।
युक्तिभवियुक्तिरस्मते शेषकाशुरुणाहतम्।।
उदयर्वेदुक्तकथयां व्यासाचर्घुरुद्वत्तम्।११३।।
राहुनमाण्यलम्भाच विशेषंश्च प्रसाध्यते।।
मध्यकालिनिषिस्वज्ञानकाण्डयोरकर्तितवत्।।
योगो विवोगो वाजस्त्रेषु मध्यव्या शेषसंवभाषाः।।
वचनमयः पलकालिनिषिस्वप्पणवतः वथात्।।
योगविवेकेश्च जीवा मध्यव्या शेषसंवभाषा।।
स्वमध्यव्योदयवालां विशेषतानिषिस्वप्पणवत।।
मध्यज्ञानवर्गतोपस्य ।।
श्वदृढःकृष्णम् पदं विदः।।
गतगतविद्वेदान्तीविशेषं तूर्वक्षलकर्तमणः।।
साध्‌या रवेशशशान्डुकः विद्यानिर्मिदमुच्यते।।

1-11 मध्यलम्भ A, B. कन्यामेदन्त्वशीर्मान्विज्ञानवाचीविवेकः A; कन्यामेदन्त्वशीर्मान्विज्ञानवाचीविवेकः B. कन्यामेदन्त्वशीर्मान्विज्ञानवाचीविवेकः C. प्रकीर्तितः C. जापनं च स्ववश्चेषु A, B. यवविद्वाचनं ब. परन्तु हुता। भास्वतं स्वप्पुः A, B. श्रीमद्वृट्टकुसुरविदः।।

This verse is missing from A, B. स्वमध्यव्योदयवालां विशेषतानिषिस्वप्पणवत।।

A, B; स्वमध्यव्योदयवालां विशेषतानिषिस्वप्पणवत।।

A, B; तूर्वक्षलकर्तमणः A, B. A and B read दृष्टेण in place of दृष्टेण. गतगतविद्वेदान्तीविशेषं तूर्वक्षलकर्तमणः A, B. भवेच्छ-शान्त शान्त A, B.
धृत्रेषुपङ्कितेः विषयेऽर्पणमपि

तितिकादिति: महाका: श्रीवर्गाकांक्षेर खुशी

धारिति: भवेतं ते भास्करमूलादेवेजसी

स्त्रृशास्त्रमायासब्राह्मोधेनसंधि

पृथ्वीहानुवके तिरं अपन विश्वास: स्वरूपां स्वप्नाय: भानु: भवेतं स्वरूपां

तितिकादिति: तत्त्वं उपलेे: सर्पास्वरूपां मत: स्वरूपां

दिनार्थकालमिति: लम्ब्वन: श्रीवर्गानी

उद्धरणामणियां दीध्यते तन्त दक्षिणे

एवं पु: पु: कर्म याचारत्वातिथि: ति

तितिकादिति: तत्त्वं विश्वास: भानु: भवेतं स्वरूपां

स्वरूपां नामध्याय: विषयावस्तुल: तत्त्वाद: सन्धि

अभिभाषाष्टूमृतेऽविश्वेषस्तथा: पूर्वित्वान्तं

मध्यज्ञयोरस्तथाय: योगावतातिथितं

दिक्त्व तन्त शिषयो ग्रन्थं पाठीतन निराधार: से

ज्यों वस्तवदितिश्रव्ये: भ्रुणां कलाकृतं भावं: सन्धरे: से

विशे: श्रीवर्गज्ञ: स्वरूपस्वातु: भावत: नति: स्वरूपां

नानाशेषी: श्रीवर्गज्ञ: ग्रन्थं: सा नतिङ्चयते से

लम्ब्वन: तन्त्रसंन्यात्स्वात्मातिथितंशिषयो: से

धृत्रेषुपङ्कितेः विषयेऽर्पणमपि

संबंधसूक्त: से

लिपि: अ, ब; लिपि: ए, ब

तितिकादिति: अ, ब; दिनार्थकालमिति: अ, ब; पृथ्वीहानुवके तिरं

This verse is missing from A and B. This hemistich does not occur in A and B. In C the initial word एवं is missing. लिपि: ए, ब; अभिभाषाष्टूमृतेऽविश्वेषस्तथा: से

योगावतातिथितं: अ, ब; ग्रन्थं: सा नतिङ्चयते से

संबंधसूक्त: ए, ब; संबंधसूक्त: ए, ब; संबंधसूक्त: ए, ब; संबंधसूक्त: ए, ब.
सुप्रभविन्यसमपण्डितन सदृशी नतिः।
ग्रहणं भास्तीं न स्याद्वीनायाममिति सम्भवः ॥३॥
सम्प्रदायतिनिविलविशेषपदमाह्यतमः।
कषमच गत्यन्तरैणाम्:। सीतायथ्यथविचकाः: स्मृताः। ॥३४॥
अविवेशपतिसतिसताभिविधीम् सहिता सदा।
प्रासादिमोक्षकाली स्तः। तास्यां जीवाविभिन्नस्तिदा ॥३५॥
प्रासमेक्षित्वनिविन्यसलम्बनात्तरनार्दिकाः।
सीतायथ प्रकृष्णप्रियों ग्रह्यैः। तिमदीविते: ॥३६॥
मध्यान्तलम्बस्तिस्थाया वर्त्ते। मश्कसम्भवः।
सीतायथमित्रस्तिप्रवतमुखिश्रुत्वेऽवज्रम्बन्धते ॥३७॥
स्वर्कमीयैं यदायन्सिमक्षपले प्रहक्ष्यतः।
स्वर्कों लकङ्गन सर्वे देयं सीतायथ्यथङ्गाध्यः। ॥३८॥
मोदेश्येवं तदायतः। सीतायथः दीयते सदा।
दिनावर्त्त शासमध्ये व कल्पन्यन्यविविधाः। ॥३९॥
प्रासमाहकविम्बाधिविवेशेष्ठक्षप्पगः।
विवेशस्य पदं नेयं विम्बाधिस्य लितिकाः। ॥४०॥
तीक्षणां विवेशस्यन्दाल्पितकालसंप्रमुः।
स्वर्कातो भवेत्रस्यो। भूमुर्वाहिवस्वतः। ॥४१॥
मध्यतिध्यत्तरासुखासुकमलम्बास्तश्रुद्धुः।
विष्कम्भार्यौ। भक्तत्वव्यः। लालकाठंस्य दिवरिघ: ॥४२॥
व्यासाधिकारायौ। वनवनः। दीक्षितः। नकङ्गे प्रासादसवलितः।
हस्तान्तरः वनुवन: प्रासादसवलितः। ॥४३॥
उदमदिशानः। प्राङ्गे। विनाशप्रार्थचार्यायोऽ।
नभावः। पश्चिमे व्यस्मक्ष्या वलनाः सदा ॥४४॥

१ विष्कम्भार्यौ। विनाशप्रार्थचार्यायोऽ। पश्चिमे।
२ पश्चाद्वत्सार्थवाणाम्। भवेत्रस्यो। भूमुर्वाहिवस्वतः।
३ विनाशप्रार्थचार्यायोऽ। भवेत्रस्यो। भूमुर्वाहिवस्वतः।
४ मध्यर्थप्रार्थचार्यायोऽ। पश्चिमे।
५ विनाशप्रार्थचार्यायोऽ। भवेत्रस्यो। भूमुर्वाहिवस्वतः।
६ सुप्रभविन्यसमपण्डितन सदृशी नतिः।
७ बुद्धानुसारसार्थप्राण: परा:। व्रजस्यो।
८ ग्रहणं भास्तीं न स्याद्वीनायाममिति सम्भवः।
९ सीतायथ्यथविचकाः: स्मृताः।
विराजितसहिष्णुकिषपरीतगुणापमः ।
अयनायिकुः पूवचिङ्ग विस्तृष्ट्यंबन्धरंविन्यंशः ।
नानायोरतपनिविश्वं विशेषं: घनुनिनोः: सदाः ।
संयोगोस्यत्र तद्भवा सम्प्रविक्षंहता न हुता ।
विष्णुभाधिने यलचन्द्रमशासामेये युतः नती ।
विश्लेष्यो व्यत्येषः कायोऽदलं तद्व, विस्मृते ।
मूलविभवस्तुस्तुक्षप्रकर्पणिकुरादशोभिना ।
अधिकशालाणुलत्वासमसस्त्रोभूमिनाः ।
प्राच्यप्रवात्मामने कर्केनानविकेश्वरिनी ।
प्राच्यप्रवात्माकम्बार्धसमवक्षेण चापरमस् ।
पूर्वविपि तत: कुर्मिन्नीनेनौतरदक्षिणे ।
दक्षिणोतरत: केन्द्राकील्वः बलनमण्यतः ।
उत्तादु तद्व मस्याङ्कः युक्तः सूक्ष्मः नयेद्बुधः ।
वाहमण्डलसंस्कन्तसमाते विनुनिश्चयः ।
बिनुत: केन्द्रसमापिये सूक्ष्मः तस्मातः प्रसायने ।
तत्त्वप्राप्तिष्कृष्ट्र सम्पातीः यत्र लक्ष्यं ।
तत्त्व तीक्ष्णाशुप्रेमस्य प्रदेशौ स्वर्णोऽश्योः ।
मौरिकाधिरुप्ताः ज्ञे धर्मः वा लक्ष्ये दिवी ।
नत्यसंयुक्तविशिष्टतः बलनं ग्रहमध्ययज्ञः ।
तत्त्वोस्तुत्त्वकाण्डवः बलनं पूर्वांतः नयेतु ।

"वम: A, C । लमावा दितः A, B । विशेषवध्नःपोषयः A, B; विशेष-धनुषः: सदा C । नक्षत्रिग्नितः A, B । साम्य-पुले C । व्यक्त: C । Verses 47-48(i) are missing from A and B । अधिकार्यमुलत्वायः A, B; "भोज भूतिना C । प्राच्याधिरुप्तारामानने A, B । " पूर्वविपि B; पूर्वविपि C ।" बलमान; C । "उत्तादु तद्व मस्याङ्कः A, B; उत्तादु मस्याङ्कः C ।" बिनुत: केन्द्रसमापिये A, B । "सूक्ष्मः तस्मातः सम्पातीः A, B; तस्मातः सूक्ष्मः प्रसायने C ।" तस्मातः प्राप्तिष्कृष्ट्र सम्पातीः A; तस्मातः प्राप्तिष्कृष्ट्र सम्पातीः C । "प्रदेशः A, B ।" मौरिकाधिरुप्ताः A; मौरिकाधिरुप्ताः B । "नत्य यथाप्राप्तविशिष्ट्वः बलनं A, B; नत्यसंयुक्तविशिष्ट्वः C."
मिथ्रायोगयो: केदारतु परिक्षण प्रसारिते।
तत्रत्वनुविद्यां सूत्रं ततो मत्स्येन नीयते।
ब्राह्मणेत्र: केदारात्मकायेतत्विद्वक्षण।
केदारतदनुसारे नति सूत्रं प्रसारिते।
मध्यविनिद्वस्तदास्य स्वाभिन्नूतो स्वप्नमोक्षयो।
दक्षिणयों नती भागे यामे सौम्ये विपर्ययः।
विद्वत्वेयहुमध्यस्य कानानिद्रियोदिपियात्।
आलिष्येत्तदस्य व्यवस्त्र ग्रासमयान्तसाप्तमयू।
मध्यविनिद्वस्तरोपनस्यस्त्राधारवचनपुष्टसा। ।
काञ्चुनेत्र काञ्चुनेत्र निद्रिष्टसप्तमात्रव।
ग्रासस्य बणिज्यम यावचेत्येऽक्रमे विशिष्टं च यत्।
ग्रासमध्ये तथा सरसी विप्रवश्मगुप्लक्ष्ये।
स्यस्यविनुद्वस्तग्रास्यमात्र॥ मानसाय वृत्तमानिष्टात्।
ग्रासस्य संवेदनया: तत्रेश्वरासकल्पव।
इष्टकालविहोनैन इष्टवयणः हृदेन नृतेन।
सूर्येऽहोभुक्तिविश्लेष्येऽष्टथा लघुवृत्माः वगितम्।
प्रक्षाल्यावनेवेवेव मन्मूलव रस्सोम्ये।
इष्टग्रासवशलाका स्यात तद्वचे। ग्रास इष्टवनः।
सुरक्षाया वैण्वी शलाका" केदारात्तिरं क्रमे च प्रसारिते।
तस्यार्थेन तथा पन्न्यायः प्राप्ते" ग्रासकर्म यः।
तत्र" ग्रासमानेन वंडरेदु ग्रासविष्मकम्।
तद्वदे तथाप्रस्तायृवृत्ये ग्रासस्यमण्डकम्।

1 केदारात्मकायेतत्विदं: A. 2 मध्यविनृतः B. 3 स्वाभिनूतः A, B. 4 विपर्ययः A. 5 कानानिद्रियोदिपिया: B. 6 स्वप्नमोक्षयो। 7 ग्रासस्य संवेदनया: तत्रेश्वरासकल्पव। 8 मन्मूलव रस्सोम्ये। 9 ग्रास इष्टवनः। 10 ग्रासकर्म यः। 11 ग्रासविष्मकम्।
विमदीर्घकणार्हैं यत् स्थित्यर्थ कलासितम्।
तत्कालायणकर्त्तेन भारतविहिंसं विखण्डवेत्।।६६।।
प्रदेशसत्तेन भिमस्य कर्कोटनामाहस्ते।
परवायू ग्रहिते व्याक्तं पूर्वं चारी प्रमुखं वते।।६७।।
एवमायुश्यार्दर्शस्यायोऽस्तकालाभूतः।
काण्डावधनसंवृत्तातुपुः शालक्षम:।।६८।।
अपिकाराणं विषिज्यानं विशेषो य: स कथ्यते।
भूण्डायाया गुणा:। कल्प्या रङ्गे: कण्यासमुद्रवः।।६९।।
भागहार: शाशास्तर गणेण एव प्रक्षेत:।
शतपतिशतीलयायं व्यत्यातः श्रेण्यार्योऽयने।।७०।।
तांतः योजन: कण्या धानीयासे: भाष्यत:।
तयोक्तिसंविषये भूण्डायास्यायमाये।।७१।।
पञ्चान्हो रङ्गे: कण्या: त्रंडावप्रह्वःः फलम्।
भूण्डायास्यायमायातमर्मस्य गुणस्ततः अक्ष:।।७२।।
भूण्डायास्यायात्काला च गुणस्य तत्तम:।।७३।।
अनेके वदति। शालिनो श्रुण्डोपवेशं
हीनं गुणे यात्रिकं रत्नकाल्यात्।।७४।।
स्थित्यर्थं कालमकरं विद्यते तत्स्मिन्।
आद्यन्योपरमः सवर्गसमुपस्तः यत्।।७५।।
क्षणा: स्थित्यर्थकाले: भूकित: प्रस्थायः समाहृता।
सम्पतिते अक्ष: रङ्ग: स्थः सोके श्रेणे निग्रहते।।७६।।
विशेषस्तयं तत्स्माचः स्थित्यर्थं च प्रस्थायते।
एवं कर्माविषेषोऽऽ विमदीर्घर्थ वा पुनः।।७७।।

¹ कलासित: A, B; कलामित: B. ² तत्कालायणकर्त्तेन भारतविहिंस: लघुमुः A, B. ³ पद्धत: सूक्ष: B. ⁴ अविकायम् A, B. ⁵ मुल्लायायं गुणा: A, B; भु….. छाया रङ्गे: C. ⁶ धानीयासे: B. ⁷ चार्यास्यायं गुणस्य गुणस्य गुणस्य: C. ⁸ तथा: A, B. ⁹ In C the second half of this verse reads as follows विभक्तमण चन्द्रकाण्डः तत्तम: A, B. ¹⁰ नयये A, B. ¹¹ क्षणा: A. ¹² प्रस्था B. ¹³ श्रेण: A, B, C. ¹⁴ कर्माविषेषोऽऽ A, B.
विक्रेर: शान्ति: कल्पंश्चेत्यकाले सतां वर्ण: ।
उत्तरो दक्षिणे निर्यान्द दक्षिणेश्वोतरे तथा ॥१७॥
प्रोक्तमेतद्वधूय मल्लरः
सूर्यचन्द्रमां कमाःतम् ।
कर्म चेत विदुषा समर्पितः
देवविद्वृत्ति सर्वंतस्विद् ॥१७॥

इति महाभाष्करीये पञ्चमोपद्यायः ।

\[1 मल्लर: B, यत्वर: C. 2 सर्वापि A, B, C.\]
पाठोद्यायः

स्वेष्टदेशपल्जीवया हंता
क्रियतिमिश्ठशाश्रितम् समाहरेत्

लम्बकेन यद्वात्तंतुरे
शोधेवदयेन निःशक्रेरे

अस्तं धनमुग्निः तद्विदो
दस्यनेन विधिरव स्विप्ययात्

वर्जतितिभवनस्ये शीतंगो-
रक्तमापमविसंहिति हरेत्

व्यासवर्ग्निच्छेन शोधेये-
चन्द्रतोष्यनविमण्डलाशयोः

तुल्योधेनमुग्निः तद्विदो
व्यासे शशिनि तत्त्वनि सदा

दृष्ट्यचन्द्र इति कथ्यते बुधे-
रेवमाकलितचारसञ्चयः

भास्करेन्दुविवंशाकोज्जून-
प्राणराकिष्ठिताकद्वये शशी

दृष्टयेन स्विदितप्रतारी
भास्करेन्द्रस्मिरिष्टग्रहङ्गोऽभ्रोः

चन्द्रभालुकवं रेतकप्रभया
चन्द्रभालुकवं भाजेवत्

पश्चायात्रसंहिताः सितं
निलयमेव गणकाः प्रजायते

"शिल्पिनिश्चारिनिजः । ते तस्यः A, B. " विषयेन: A, B, C. "वर्जित तिमिश्यातः क्रियानि तत्र सूक्ष्मदर्शि ।"
"श्रिवमापमविसंहिति रक्तमांकम् साधु " तत्त्वनि ।
"व्यासवर्ग्निच्छेन शोधे चन्द्र तोष्यनविमण्डलाशयोः।"
"दृष्ट्यचन्द्र इति कथ्यते एव " रेवमाकलितारसञ्चयः।"
"महाकालितारसञ्चयः।" शशी।
"भास्करेन्दुविवरंशकोज्जून प्राणराकिष्ठिताकद्वये।"
"दृष्टयेन स्विदितप्रतारी भास्करेन्द्रस्मिरिष्टग्रहङ्गोऽभ्रोः।"
"चन्द्रभालुकवं रेतकप्रभया चन्द्रभालुकवं भाजेवत्।"
"पश्चायात्रसंहिताः सितं निलयमेव गणकाः प्रजायते।"
चन्द्रभानुविवरणे पदार्थिकः
स्यात्तसा कम्पित्वेन युक्त्वेन। १६।।
श्रव्या सिद्धिविशिष्येते
पौर्णमास्त्यपरतोषिते तथा।।
सूर्यचन्द्रविवरणाश्रीवाय
चोलकमधुक्रिष्ट्वासिते विजुः। १७।।
चन्द्रमोपमविकाष्ठयोरूपिते
स्तुत्यगोलभवयोरसूर्यथा।
काष्ठयोविवरतोषिमोः गुणस्तेन चन्द्रचर्मार्नासिद्धाविधिः। १८।।
भानुचन्द्रविवरणामुखिः सदा
शंकुश्वरविशिष्या विभीयते।
अक्षापगुणसंगुणं हुरे
लम्बकेन शामिकौलं स्फुतम्। ९।।
कोलकापगुणं आयत्ते ततो
नित्यदक्षिणगतोस्तम्भौः।
गोलखण्डगुणितो विभुज्यते
लम्बकेन शामिनोपमः स्फुतः।। १०।।
दक्षिणोत्तरविशोभिनिशाङ्कूः
लम्बतेजयुगसंकितः।। सदा।
तुल्यकाष्ठयोद्योगस्यौतः
गुरुदेश्यमधुरयोगस्योविच्।। ११।।
भादरमश्रयुगकेन तस्य तु
व्यतियेन युत्षकोद्वे कृते।

¹ भानुचंद्रविं C. व्दार्थिक A, B. ² युक्ते B. ³ उपयुक्त B. ⁴ गुरुमानव सतोसित A; पूर्वमात्वरतोसित B. ⁵ चन्द्रभानवविं A, B; चन्द्रमोद्विं C. ⁶ काष्ठहोनारस्त्रपोरो A, B; काष्ठहोनारस्त्रोपो C. ⁷ In B, 8(ii) and 9(i) have been interchanged. ⁸ गोलखण्डगुणिते C. ⁹ यथार्थमण्यम स्फुत: A, B; शामिनोपमस्फुत: C. ¹⁰ "कृतो: A, B. ¹¹ लम्बते श्रयुग संकित: C. ¹² "दृष्टि: A, B, C. ¹³ गुरुदेश्यमधुरयोगस्योविच् C.
बाहुकः शशष्टि: स्वर्षो नमः ।
कोटिरः शशष्टि: द्विबिंतियः ॥ १२॥
सूर्योऽङ्गायेऽर्थः बाहुः कोटि: 'पुरारिवत्यतः' ।
बाहुः कोटिमिरः: अङ्गेण सूर्यः करः: प्रकीर्तितः ॥ १३॥
केष्कोष्ठव्रतान्यतः शशष्टिभवां समालिष्टः ।
तस्य पूर्वपरः कर्मेऽस्मिन्याद्विकिर्षणोऽर्थः ॥ १४॥
विशेषत: र्योऽविन्दुः चन्द्रविमेव समालिष्टः ।
करः श्रोतानुसारेऽश्रुतः सन्त्सिसतिविन्दुकः ॥ १५॥
तद्विद्वद्योऽस्मास्यतः: पूर्वविकिर्षणोऽर्थः सतः ।
तत्र श्रीसताउऽविस्मित्व विवरः: शोकलयुक्तः रथतः ॥ १६॥
श्रुः: वोऽविन्दु: श्रीसताऔऽस्मित्वमुलयुक्तःतः ॥ १७॥
अस्ताकः। 'व्यावेशतिद्विवात्तलकया'।
ततःकोष्ठयोऽस्मित्वाद्विकिर्षणोऽस्मित्वादः ॥ १८॥
अङ्गयामः: परः: कल्पो: लग्नमेव विवाकः।
श्रुः: विनिकिर्षणोऽदिश्वे तत्त्वमेव सिद्धमविवाकः।
अस्ताकः। अष्टाकः। अविशेषावस्थाद्विकिर्षणोऽविन्दु:।
श्रुः: कालविशेषान्यः: विकाटित्वे विवेकः।
एवम्बात्सिसतावैकृत्यं विनिकिर्षणोऽविन्दुः:।
वाक्याश्रयोऽस्मित्वादित्वः कामसंगेऽस्मित्वः:।
रविचाराणास्त्रा अन्यः। विनिन्दुः।
वाक्यावशेषः । कामसंगेऽस्मित्वः ॥ १२॥
हेषावशेषः । कालविशेषान्यः। विनिन्दुः।
रविचाराणास्त्रा अन्यः। विनिन्दुः।
प्राकः पशुवन्दा। वृज्यातः सोमस्तावैविनिन्दुः:।

¹ बाहुकः शशष्टि: स्वर्षो नमः:।
² कोटि:।
³ 'पुरारिवत्यतः: अ, B; 'पूर्वपरः: C.
⁴ The second half of verse 14 and the first half of verse 15 is missing from A and B both.
⁵ भिभ्राधिणि: अ, B; 'श्रृः: तत्त्वादित्वान्यः: मानविभवान्यः: A, B; श्रृः: तत्त्वादित्वान्यः: मानविभवान्यः: C.
⁶ मुलम्भः: A, B.
⁷ अस्ताकः: C.
⁸ 'The first half of verse 19 is missing from C.
⁹ ध्वनिनिविवाकः: A, B.
¹⁰ विशेषध्वनिविवाकः: र्योऽविन्दुः:।
¹¹ 'श्रुः: शिवान्यः: मानविभवान्यः: युद्ध:। A, B.
¹² अ, B.
¹³ 'स्तुः: । अस्ताकः: C.
¹⁴ 'श्रीशिष्योऽस्मित्वः। रविचाराणास्त्रा अन्यः: A, B.
¹⁵ रविचाराणास्त्रा अन्यः: C.
¹⁶ वादित्वः: C.
पश्चात्तापरि: सोमो हरिजारुपकोरि सिधत:।
इष्टकालविलमोक: प्रमाणः परिलिख्यते।॥२३॥
कोटि: पूर्वीप्रति: कार्यं भुजा याम्योतरायता।
अत्रो कोटिष्ठितं: यूक्तं कार्यसूच: प्रसारयते।॥२४॥
पूर्वः: कुष्मूँच: सिद्ध: प्रवेशयते।
असित्वा वा परारभमर्गशीलताः: परिलिख्यने।॥२५॥
अथवायात्तवे: कार्यं तत्कलेनकर्तनमभवः।
सिद्धान्तस्य पूर्वः: दृष्टिकालोभिषेषमध्ये॥॥२६॥
शराशिशुक्तसूत्रे: दुःखप्रवचनराध्यवाचः॥
अविशिष्टश्च: सिते पर्यं दृष्टिकालोपछ: परसः॥॥२७॥
चक्राधोपुत्रीक्षणोधिश्रुतानां: करणागताः॥
अत्रेयान्तरप्राप्तिस्विकीर्ष्याम्: दृष्टि: शशी॥॥२८॥
अस्तकालितिवन्दनः वृद्धमध्याध्यसः॥
कलेन लक्षणशः॥ कृतव धूमोध्यासः॥॥२९॥
पूर्वकालेन ते दीर्घान्तः: लक्षणाधिकोशः॥
विशेषीय: वाजयथा यावत्तुत्त्रकालोद्देशः॥॥३०॥
इत्यं कर्मक्रमवाच्यात्तवे: लक्षणमूलवेषः।
राममिण्ड: पूर्वथाय: निषीद्येऽनुष्ठि: दृष्टि: शशी॥॥३१॥
अस्तादिद्रामहाकालितिवांशुमार्गः।
स्वेद्येऽन्नोध्यप्राणः॥ प्रायो यावत्तिष्ठानां॥॥३२॥
पुष्पवहमनस्यार्जुः: राजाः: युष्टेषु: चतुः॥
दृष्टि: तविष्ठितेषु: तस्मात्तानविलेषे॥॥३३॥


१६ तविष्ठितेषु: तस्मात्तानविलेषे: C.
तद्वधिकोभोगसंगुणस्वपन्नन्दत्तथंकमान्।
ततोज्ञर्वनसंशोधः सेषप्रगाधिकर्मणा।
अर्कन्दूरमध्यांनार्धिम्। दिनमानं विवधते।
तत्रिस्मषयुष्टिः दिवा चन्द्रोदयः! स्मृतः।
तत्रार्काङ्क्षापापात्मोगह्रींनार्कचन्द्रयो।
अन्तरालोदयप्राणि: कल्यं तत्राविशेषणम्।
चन्द्रावीदविकात्त्राणि: बालानावदिकोऽरवः।
ग्राह्यास्ततोपि विलेषात् कल्यंते निष्ठ्वलिक्या।
क्रताविशेषनार्दीभ्रोऽविशेषेदीर्भा: भाष्करः।
तावद्रामुच्चावाद्यः; प्राणेरारक्तमेति शरी।
आसनी स्वपपियाः; मध्यपननिशाकारी।
कालेनुमध्याल्मनामविशेषं समाचरेत्।
नाइयोऽत्रालजः। साध्या लक्ष्यारायूत्त्योऽऽ।
उनेन विलेषपादीय:। शुद्धि: केसपक्रिके स्मृतः।
मंग्लयाससम्मचन्द्रो जायतेन्नेन कर्मणा।
तत्रिथ्यपकमार्क्षस्तु मध्यचढ़ाया प्रसावयते।
अर्धाविद्यस्य चन्द्रस्य तथा। अवस्थितिः।
इन्द्रावस्तलमाग्रे:; दृष्ट्वोत्सरोत्तक्षत्षा:।
कर्मणं शक्तिस्तस्य कुरुवृद्धावर्जिते।
पद्यारामिकं सर्व्यामिकं कर्म विधिते।
अष्टित्वरित: सत्यानामबिधूतं भूमु:।
द्विचित्रैःचित्रविकृतं द्वारा यौज्ञारिष्टरामुतं।
प्रत्येकः सहर्मी सितो वृस्यायपनचः।
चतुर्थिभिःसुमालितवादशेषरसमतृत्वे।

\[^{18} संयुक्तः A, B. \]^{20} अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्।

"The second half of verse 36 is missing from C. \(^{+}\) चन्द्रावीदविकात्त्राणि: प्राणा। " बालानावदिकोऽरवः। " क्रताविशेषनार्दीभ्रोऽविशेषेदीर्भा: भाष्करः।" तावद्रामुच्चावाद्यः; प्राणेरारक्तमेति शरी। " आसनी स्वपपियाः; मध्यपननिशाकारी।" कालेनुमध्याल्मनामविशेषं समाचरेत्।" नाइयोऽत्रालजः। साध्या लक्ष्यारायूत्त्योऽऽ।" उनेन विलेषपादीय:। शुद्धि: केसपक्रिके स्मृतः।" मंग्लयाससम्मचन्द्रो जायतेन्नेन कर्मणा।" तत्रिथ्यपकमार्क्षस्तु मध्यचढ़ाया प्रसावयते।" अर्धाविद्यस्य चन्द्रस्य तथा। अवस्थितिः।" इन्द्रावस्तलमाग्रे:; दृष्ट्वोत्सरोत्तक्षत्षा:।" कर्मणं शक्तिस्तस्य कुरुवृद्धावर्जिते।" पद्यारामिकं सर्व्यामिकं कर्म विधिते।" अष्टित्वरित: सत्यानामबिधूतं भूमु:।" द्विचित्रैःचित्रविकृतं द्वारा यौज्ञारिष्टरामुतं।" प्रत्येकः सहर्मी सितो वृस्यायपनचः।" चतुर्थिभिःसुमालितवादशेषरसमतृत्वे।

\[^{41} संयुक्तः A, B. \]^{27} अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्। अर्कन्दूरमध्यांनार्धिम्।

"Verse 41 is missing from C. \(^{+}\) ग्राह्यास्ततोपि विलेषात् कल्यंते निष्ठ्वलिक्या।" क्रताविशेषनार्दीभ्रोऽविशेषेदीर्भा: भाष्करः।" तावद्रामुच्चावाद्यः; प्राणेरारक्तमेति शरी।" आसनी स्वपपियाः; मध्यपननिशाकारी।" कालेनुमध्याल्मनामविशेषं समाचरेत्।" नाइयोऽत्रालजः। साध्या लक्ष्यारायूत्त्योऽऽ।" उनेन विलेषपादीय:। शुद्धि: केसपक्रिके स्मृतः।" मंग्लयाससम्मचन्द्रो जायतेन्नेन कर्मणा।" तत्रिथ्यपकमार्क्षस्तु मध्यचढ़ाया प्रसावयते।" अर्धाविद्यस्य चन्द्रस्य तथा। अवस्थितिः।" इन्द्रावस्तलमाग्रे:; दृष्ट्वोत्सरोत्तक्षत्षा:।" कर्मणं शक्तिस्तस्य कुरुवृद्धावर्जिते।" पद्यारामिकं सर्व्यामिकं कर्म विधिते।" अष्टित्वरित: सत्यानामबिधूतं भूमु:।" द्विचित्रैःचित्रविकृतं द्वारा यौज्ञारिष्टरामुतं।" प्रत्येकः सहर्मी सितो वृस्यायपनचः।" चतुर्थिभिःसुमालितवादशेषरसमतृत्वे।
कालभाषा: कमेणंते विन्हना' विष्ठिका:’ स्मृत:।
एक्ष्येः तद्राशिष्या श्रेया वारण्या सप्तमस्य तु। ॥४६॥
प्रहस्यांतरावणाट् श्रीिता स्वोद्य हरेत्।
लख्यालो निःस्तेन यदा तुल्यस्तत्त्वोय:। ॥४७॥
मन्द्रोवकर्णगुणं श्रीिवर्णसंविधायेऽि।
विष्ठिकम्बायों सस्वयो भागहर: प्रकीित:। ॥४८॥
प्रहस्यार्तरभाज्यत्र प्रतिलोभानुलोमय:।
भुक्तियोगने शेषानां भोगविश्वेयसंविष्ये। ॥४९॥
दिनालिनं भीते कालो योगिनं योगकारक:।
भुक्तितेनकपपत्नाल स्तुति: कालोज्ज गम्यते। ॥५०॥
समलिप्ति ततो' युक्तया कुष्ठातनस्य वैदिता।
स्त्रोपदेशादुगुरोनिर्मयमयसेनापि गम्यते। ॥५१॥
पातालागच्छ्वीिनस्य समलिप्त: जीवया।
हलवा सदा स्त्रविकारपि भगहारेऽभाज्येऽ्। ॥५२॥
जीवभौमार्कुश्चन्त्रानापि स्विभेषकल्पन।
शीिमच्छ्वाद्वच्छावस्थापि स्विभेषो दश्तिणोत्तरः। ॥५३॥
भिभिभिभिकानो तु विभेषो युक्तातत्तरमिष्ट:।
तुल्यस्निकानो विभेषणः” विभाविवरलिपिकाः। ॥५४॥
पादाद्गुरकलाद्विधा यथा। वा लक्ष्यते विधि।
तदन्तर्ते तपोभिष्यं योगिनं योगकोविधः। ॥५५॥
द्वाभिष्कर्णधभीितः भूयो भूयस्तुतः।
श्रुत्योवािक्षिपिनामि” व्यासलिप्ताकस्म विदु:। ॥५६॥

¹ द्रिष्टा A; दि् C. ² विष्ठिका: B. ³ ऐदे A, B. ⁴ सप्तम स्मृतम् A, B. ⁵ प्रहस्यान्तरावणामि A; प्रहस्यांतराशना B. ⁶ तुल्यस्तत्त्वोय: A. ⁷ स्मृतिः A. ⁸ मुख्त: A, B. ⁹ दिनावत् सम्यते C. ¹⁰ स्थूलसम्यगे् C. ¹¹ समबिपत्ति: B. ¹² मोहम्मत्तरुद्धा C. ¹³ सोपदेशादुगुरोनिर्मयमयस्य वाकेश्चते C. ¹⁴ वात् A, B. ¹⁵ निश्चयान् A, B. ¹⁶ समस्याविष्य A, B; सदास्य कीवर्ण A, B. ¹⁷ दश्तिणोत्तर C. ¹⁸ यथा C. ¹⁹ तुल्यभिराघुस्थिति C. ²° विभाविवरलिपिक A. ²¹ वदाद्गुरकलाद्विधा यथा A, B; पादाद्गुरकलाद्विधा सन्था C. ²² श्रुत्योब्ज्ञानं क्षिपिनामि A, B; श्रुत्योभासगीनामि C.
एतैरेत्त हृतः कर्णशचन्द्रयोजनजः क्रमात् ।
लम्बनादितु हारः स्या मानायोजनमास्त्रितः। ||५७||
विषक्माण्डः हर्षव्या भाग्हारहतः स्फुटः ।
भाग्हारहतः व्या स्या व्यासार्धवच्च लिलिका। ||५८||
शेषः सीतासुवेष्टकार्यं दणजीवविनिषच्छमः। ||५९||
चन्द्रोदयोपवेशो शंकुः स्यात् स्वचराविभि। ||६०||
स्वहारिश्रेष्ठयोगेशु लम्बनावनती विदुः।
ग्रहोतरागुवऽप विस्थत्वच्चिदिविधिक्रमः। ||६१||
इति प्रतिदिनायम्पासविंमीलीकृतेऽतसामः।
गुह्यसादसस्माप्तशस्त्रसद्धार्वचक्ष्यामृ। ||६२||
नाययास जते वाणी ग्रहारात्यायिनी।
रम्यानुरस्तकार्यास्विनितत्वृतिरिवामला। ||६३||

इति महाभास्करायेष पण्डितर्च्यायः।

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1 एतैरेत्त हृतः A, B; एतैरेत् C. । "कोजनता: A, B; "योजनता: C. । "योजन is missing from C. । "मक्तया C. । "लिप्ता C. । "The second half of verse 58 is missing from A, B. । "शेष C. । "विनिर्निग्रहम् C. । "चन्द्रोदयोऽपेशो तु A, B. । "स्यामसुरशैवो वारे C. । "कथ्यावनसतिविदुः A, B; लम्बनावनती: विदुः C. । "उत्तेजस: A, B. । "गुह्यः B. । "पाणिग्रहारात्यायिन A, B.
सप्तमोद्वयायः

शतमण्डोत्तरं भानोवचतुर्भिरयुत्रैैैंतम्
इन्द्रोऽव्रतमप्रज्ज्वलयुघयुगस्यांतः।।।।।।
सागररसस्यप्रवेदीविविष्कसमः।।।।।।
वेदाचार्यविज्ञातोऽवित्तः।।।।।।
कलद्राक्षरुर्मण्डितीमः।।।।।।
बुधभृगवोत्स्ते श्रेष्ठस्मी श्रीप्रभुवेयः।।।।।।
इवृवस्य नवेकपाधिविनिःस्त्यकुलसंगीतः।।।।।।
बुधस्य खातविस्तारंविनिःस्त्यलक्षणाः।।।।।।
भृगोविस्तारारामविनिःस्त्यस्मिनः।।।।।।
राहोऽविधिकनेत्रविचित्रितिः।।।।।।
स्मृताः।।।।।।
अहःपुरानवर्मायिनिःस्त्यविनिः।।।।।।
हरदशर्यं युगं भानोर्भीगःहारोदिकातः।।।।।।
अवमय व्योमवस्त्रप्रथतिःतब्धविविनो।।।।।।
व्रत्योमामधृश्वाभिनिःकालः।।।।।।
हार इत्यते।।।।।।
व्योमविज्ञातातांतिघमुद्राद्विहर्।।।।।।
युगस्य दिवसः।।।।।।
प्रेक्षात् विशेषांश्च शास्त्रः।।।।।।
परम्।।।।।।
युधस्तुमिनिब्रजान।।।।।।
हँसपक वचसा तं पते।।।।।।
सार्थाः।।।।।।
स्तितिपुनः पात्मानः।।।।।।
क्रमेण च।।।।।।

¹ भानोज्जुर्वेश्वर्युत्तम् A, B.
² भृगोविचारिनिःतिः A; भृगोविचारिनिः B;
³ भृगोविचारिनिः C.
⁴ सागररसस्यप्रवेदीविविष्कसमः A, B.
⁵ सागररसस्यप्रवेदीविविष्कसमः C.
⁶ श्रीमाधवः A, B.
⁷ वनितरश्राकरनिःकालः A, B.
⁸ सङ्कोचविस्तारारामः A, B.
⁹ भृगोविस्तारारामः C.
¹⁰ गुणा: A, B, C.
¹¹ वेदाचार्यविज्ञाताः A, B.
¹² हरदशर्यं युगं भानोर्भीगःहारोदिकातः A; 
² हरदशर्यं युगं भानोर्भीगःहारोदिकातः B.
³ अवमय व्योमवस्त्रप्रथतिःतब्धविविनो A; 
⁴ अवमय व्योमवस्त्रप्रथतिःतब्धविविनो B.
⁵ व्रत्योमामधृश्वाभिनिःकालः A, B.
⁶ सार्थिः A; सार्थिः B.
विशालिति: संसाधिकारियां शतं खांटी खसागरा।।
उदगाहारिनिविषयानुः पाल्यहीनाद्विनिरिविशेषत् ॥१०॥
आशाधिवन: लार्या प्राणिन: रसविविषयकाजिवनः।।
खांटीडोडोडोय्यलहस्त दमत्वं शीतंप्राच्चोधि। यथाक्रमम् ॥११॥
भास्करस्य विज्ञानीयाद्विप्रस्तुतिमशकावा।।
स्तमदोषेष्व ग्रहान्वेयेऽर्थं शीताण्वेयोध्या यथा:। सदा ॥१२॥
सत चत्वारी रसाचार्य परिव प्रवत्स मनव: कमातु॥
एकादशशब्दाभिनव नवचारितिनिवेष्ठः ॥ १३॥
म्भरकोष्ठकृतानि विदाहु विषमयोर्विः।
समयोः पदयोक्तापि कथ्यन्ते मदन्तेषांशोः ॥ १४॥
शिलोमुखाविवनोज्ज्वेकवस्वरोक्तादस्यः ॥ च।
नवाध्विन्यो नमर्यः वस्वर्यः: कमानु ॥ १५॥
एकादशाक्षरः चौथ सूर्यच्छुद्रस्तोरतं ॥
विषुकम: क्षितिज्या ॥ जीवा मख्याद्वि मिता: ॥ १६॥
मख्यादिर्गहुतं करं ॥ विकस्ये ॥ तत्समास्तः ॥
नारदाशकस्मृहाद्विबिभोधस्य ये ध्रुवाञ्चलः ॥ १७॥
तन्थेरण्णिताः ॥ ब्रह्मा: ब्राह्मा: खालेऽज्ञानाधित: ॥।
चतुर्दशील रैस्य भ्रमणमन्त्यत्वः हृतम् ॥ १८॥
बाणाकोष्ठ्योः। फलं कुसनं कमोक्तकमुणः स्वयम् ॥
लम्योत्क चत्रस्तीद्वाविङ्गस्ता: वापि तत्त्वः ॥ १९॥
इदंगम्: लखवियदस्वर्वदिनन्त्या: ॥
योनिः भ्रेयुरिः वृत्तमानसंश्च या।
इष्टग्रह्यरूपम्। भगणगृहस्य बुद्धत्वम्। तत्र परिधिः लभते समतात्।॥२०॥
विवचनः कर्मणां प्रेक्षो योगावौधिको विचित्रः।
अर्धरात्रे तथा सबों धो विशेषः स कथ्यते॥२१॥
तिसति भूमिदेिे क्षेप्या ह्याबेमयोऽविशोच्यते।
जगुर्वोऽंगणेयापि विशालितवच ततोऽवच्यः॥२२॥
अद्वितस्तगुणः ह्यासो योजनानां भूवो रक्षे।
खण्डाद्विधयानिन्ति शीतांशोऽऽुस्यवस्वद्यस्यस्यस्या॥२३॥
विष्णुविण्णुण्णिशृङ्गद्वद्वस्यज्ञानीऽविभावऽः।
अंतुजः ज्ञेष्वक्षुभतानि चन्द्रकरणिः प्रकृतितः॥२४॥
अद्वितरीति जिना र्द्द्रा" विशालितवचधिका" कमात्।
दशश्च। गुरुशुकाकाफळभांमानः। स्वमन्द्रजः।॥२५॥
मन्दवल्तानि ह्याज्ञावासनवः।" पर्यार्था"
वायुः बमुद्वसः। स्यः श्रीवर्तात्न्यध कमात्।॥२६॥
वेच्छः। सामुद्रेनवाणि खाल्ययोज्यधनिशद्यः।
वेच्छनीन्द्रवः। रद्वमंदः। शुकवद्र वृत्तमेव च।॥२७॥
एकप्रियाश्च भास्तुवर्यावृत्तिः विदीयते।
पातभागावः। विषेयः। परीतिः परिकृतिः॥२८॥
मन्दशीरसोच्चः। क्षणेचकार्य कुथुमुक्तः।
राजित्रः तू श्रेयायां पात्येन पातिसंद्रीवः॥२९॥
श्रुयणकिर्दृश्यानां भासो ह्यावेव संगुति।
मन्दपातास्वतः शीर्षोभच्छः। सार्ज्ञास्तु कुञ्जयः॥३०॥

" परिधिभाष्यमेते समतात् A, B; परिधि लभते समातात् C. अर्धरात्रेच्छवः A, B.
" विशालितवचनः A, B. ह्याबेमयेको A; ह्याबेमयेको B. " भुग्नम्बरणेयापि C.
" अद्वितस्ता B, A. " शुर्यवस्वद्यस्यस्य S; शुर्यवस्वद्यस्यस्य C. " विशालितवचधिका।
" विशालितवचधिका B, C. " श्रीवर्ती B, C. " अद्वितस्तानि A, B; श्रीमास्तानि C. " मन्दवल्तानि A, B;
मन्दवल्तानि C. " र्द्द्रा A, B. " गुरुशुकाकाफळभांमानः। " रद्वमंदः A, B, C. " श्रुयणकिर्दृश्यानां A; श्रुयणकिर्दृश्यानां B; श्रुयणकिर्दृश्यानां C.
" श्रुयणकिर्दृश्यानां A, B. " रद्वमंदः A, B, C. " अद्वितीय C. " अद्वितीय A; तेजामो B; पात्येन C. " मन्दीच्छः. C. " वास्तुसक्ति A, B.
" मन्दपातास्वतः शीर्षोभच्छः। मन्दपातास्वतः शीर्षोभच्छः C. " भुग्नम्बर A, B. 

विद्यानां च सर्वां शीघ्रपाताः प्रकृतिताः।
शोधविष्ठ्रा कमात् पातान् विशेषपांगानाः प्रसाधयेत्॥३१॥
योगविष्ठ्यपांग्यक्रमेकस्वदिविभवानुः।
विक्षेपः स स्पृष्टो शेषो गहवस्यकर्षण कृतित:॥३२॥
अनयस्यापेवभे स्याण्डेशा: प्रागुक्तकल्पनाः।
एतत्सर्वं समासेन तम्मांतरमुद्रहमृत:॥३३॥
श्रीध्रमन्दोष्ठवापार्थसंस्कुलात्स्तर्थीयमन्द:॥
स्पृष्टमध्यग्रहः: सवे विशेषः परिकृतित:॥३४॥
बेदाशिरामगुणितान्यमुदाहातानि
चन्द्रस्य शून्यरहितान्यमुदाहातानि।
स्व: स्वस्हृर्तानि भगणे: कमशो ग्रहाणां
कश्या भवति खलु योजनमान्दृष्टानि॥३५॥

इति महाभास्करीर्मे सप्तमोऽध्यायः।

\[\text{कृतिता: C.} \quad \text{कमात्वादिक्रियांपाताः A, B; कमात्वादिक्रियांपाताः C.}
\text{रनेकःस्वदिविभवानुः C.} \quad \text{श्रीध्रोमः A, B} \quad \text{स्पृष्टमध्यग्रहः: C.} \quad \text{विशेषः A, B.}
\text{चन्द्रस्य:} \quad \text{स्वस्स्वृत्तानि भगणे A; स्वस्स्वृत्तानि भगणे: B.} \quad \text{योज-}
\text{नमान्दृष्टाः A, B, C.} \]
अष्टमोष्णयायः

शति।शति.
सार्वाचूक्रोष्टकलाबिम्तीं

शतया दिनाबं सम्भविभागें।

पञ्चाङ्गुलाः द्वाधसकर्म गंिऽं

वेदार्कमिनिद्विनमध्यातमः॥७॥

अष्टीं लयः: गोगशलितविभागः

पलभ्रमण् त्र्यवेदर्तीयमि सरस्वती।

छाया दिनार्थे द्वे त्वचार्थे कुमारस्थैः

तत्राशु वाचः: नरवित्त नरस्थः॥१६॥

पञ्चाधिका विशिष्टिरक्षाभागः

विशचं यस्मिन् निहिता: पलस्वः

छाया तथो: गांशुसामि दिनार्थे

सिंहं समाचक्षुः तथो: स्फुटकार्मेऽ॥९॥

अष्टाश्चाकः: पञ्चधशीवियस्मिन्

छाया रङ्गे: पञ्चभ्याग्नुक्त।

सार्वाङ्गुलाः स्थानं समस्तोलेः

वाच्योऽविवस्वान् खलु तन्त्र किद्वः॥१०॥

सप्तत्रेश्चछाया समस्तोलेः पलाङ्गुलान्त्रेश्चातः

वाच्योऽजगल्रदीपः समस्तोलस्निष्ठः सर्वत् इतिः॥१९॥

छाया गोगश दृष्टा प्रागारसमायता समे देशे।

सारीः सत्य पलाङ्गशास्त्र् विवस्वान् कियान् वाच्य्॥१२॥

नीता रञ्जे वे बलेवलवता भूण्डम समस्ता

राजायाद्योजः हरिता: सह तत्त्वराधिः।

लेये मया परिपात: खलु तत्त्वराधिः

सैकसं शतं कथे भानूमहर्णण च॥१३॥

सार्वाङ्गकाराः A; सार्वाङ्गकाराः B. 'छायाविनाभ A, B. 'पञ्चाङ्गुल A, B; पञ्चाङ्गुल B. 'गांशु C. 'सिंहमन द्विनमध्यात्म: A; आत्माशितमन द्विनमध्यात्म: B; 'गुप्तमनिद्विनमध्यातमः C. 'अष्टी लयः: A; अष्टी लयः B. 'वल्लभमण A, B; वल्लभमण C. 'तत्त्व प्रामण: नम्: स्व: A, C. 'भाग C. 'फलस्व A, B; फलस्व C. 'व्यासक्षेत्र B; व्यासक्षेत्र C. 'स्फुटकार्मेऽप A, B; स्फुटकार्मेऽप C. 'अष्टाश्चाकः: A, B. 'सप्तत्रेत्र्यास्त्र् C. 'सम्भविनयाद्योजः C. 'सैकसं B.
राशिभागसहिता: शसलिप्ता
बालहस्तपरिस्तविनिष्ठा:।
पञ्चवर्गविकला: खलु दृष्टा-
स्वाभिरायं दिनराशिशारामकू।।१७॥
राश्यशका हुता वात्या भागयोपप्रतिवति:।
वाचयो' भौम: क्रियास्त्र कीृड्ढो वाच्यवर्गं:।।१५॥
राशिन्यं पञ्चवदशांशाकुकं
लिप्ता निहावाद्युतस्य पञ्च।
एतस्मौक्ष्याय गतान्त्वहानि
यातानि तस्येव च मण्डलानि।।१६॥
मवबद्गुहराशिभागलिप्ता:
शिशुना च चलेन नाशितास्ता।।४॥
नव तत्र विलिन्तिकात्सु हृष्टा
दिनराशि गुरुमध्यमं च तामि:।।१७॥
मण्डलादि भूगुरस्य सन्ति
नवक्रम विकला दश दृष्टा।।१॥
सूर्यज्ञ्य दशा सप्तसमेता।
दृष्टि तौ दिनगणावयं श्रीस्रीम ।।१५॥
पञ्च सप्त नव भोमश्याल्की
राशिपूविगिती समवेति।
उच्चतां दिनगणं शशिभोभी
कीृड्ढो च भद्रत्रबिदाशु।।१६॥
भोमश्यकुरुमध्यविशेष:।
पञ्चवर्गशिलिगि:। परिपूर्ण:।

¹ पञ्चवर्ग विकला B, C. ² रार्थ A, B; ³ रख C. ⁴ राश्यशका A, B. ⁵ वाला भागयों विस्तरित: A; वात्या भागयों विस्तरित: B; पाल्या भाग शेषस्तु सप्तति: C.
⁶ पाल्यो C. ⁷ एतस्मौक्ष्यायवगतान्त्वहानि A, B. ⁸ नाशितास्तार्थ A, B. ⁹ विलिन्तिकात्सु B. ¹⁰ गुरुमध्यमात्तलापी: A, B; गुरुमध्यमात्तलापी: C. ¹¹ सन्ति A, B. ¹² शास्त्रमेता C. ¹³ दिनगणावथ A; दिनगणावथ B; ¹⁴ दिनगणावथ C. ¹⁵ भद्रत्र-विदाशु A, B. ¹⁶ गुरुस्व A, B. ¹⁷ संपित्त A, B.
उच्चतां दिनगणं: कलियातो
देवमिद्रिवधिरि: च किंवति। ॥ २०॥
सूचञ्छदनमोऽऽुलाध्यगतिः द्रष्टो मया तत्वबोऽ
भागेदींताॅऽाणयेन च युतो सूर्यस्य वारोदये।
लिप्ताभि: शाबिशुःत्सागरं यो जीवस्य वारे पुनः
गुरुस्य राजस्वरस्य दिवसा तुलयो क्रियाहुऽदिने। ॥ २१॥
बिलिताभिकर्षिकोऽविवेयो भूर्गरेतुऽभि:।
शाधवेच निशानाताभिरलप्त्वा गृहिसामिति। ॥ २२॥
नार्द्रीभि: किरिकीर्षर्युःपगताद्वां गणाद्वागः
स्तीत्वाण्योऽथर्वं गणाद्वागः विलयं नीतोऽतु म।
ढूःत: सत्तितरेकुपस्हिता शेषः मलनां मया
वक्तव्यो दुर्गणो गतवच सवितु: सप्ताद्वश्च यत: नार्द्रको:। ॥ २३॥
अर्जनाज्जार्-बासरणपुष्ट: कविचिह्नानां गणो
लब्धी तत्र न वेदिन्ने नष्टें तयोः शेषी मया वर्तितिः।
यो तौ मण्डलतित्तित्वम पुनर्भक्ति दिने: स्वः। पूवथक्
त्त्वतां महामातीणोन्त्वमुनि। चाये तयोस्तिन्दत:। ॥ २४॥
अर्कस्याॅऽथर्वगात्म्यानस्थिनिः शेषः कुजप्योष्यके
भूतवश्च भूतस्योष्यके रितिधिनवार्यदशमामृतः।
एतत्स्यो गुणगीणमुणियोऽर्थां गणो तदुवगां
ढूः चाचरि तत्वोऽविवगणपण्या स्वारण्यवध्यं कमातू। ॥ २४॥
भास्करे ञमिथुनपयवशाने
शर्वरी त्रियुक्तान्त्वतो भण्डात्।
अक्ष्यापणितः वद तस्मि
लम्बकैण सहितं विगणवध्य। ॥ २५॥

"देवमिद्रिवधिरि: A; देवमानिरवधिरि: B. "दिवसं C. "दिनाहिरि: A; दिनाहिरि दिने: B. "गृहिसामिति: A, B. "नार्द्रिभित्वर्युःपगताद्वां गणा भागवः। तीव्राशुःकण- शाक्तिकेन निविं नीसस्मुना A, B. "सहित: शेष: A, B. "शेष: A, B. "निवेश- नेमि च A; नवि च B. "पुनःस्थानी स्वाभिक: A; पुनःस्थानी स्वाभिक: B. "मथुरा- द्वीपवर्युः A, B. "The verses 23 and 24 do not occur in C.
"अक्ष्यापणितं C. "अक्ष्यापणितं A, B."
भास्करेन परिचितत्व कृतोऽयं
मन्दवृद्धीपरिवोधसमर्थः।
सम्यगार्यंभक्कर्मविवर्तः।
स्पष्टवाक्यकरणः समवेतः ॥२६॥
स्पष्टार्थनिककरणः छेवके यहनेः रवेः।
यदिहासित तदन्त्यत यथेहासित न तत् स्वविचित ॥२७॥

इति महाभाष्करीये एक्षमोजयः।

इति महाभाष्करीयं समाप्तम्

tat से C. कर्मविवर्त: A, B. स्पष्टार्थनिककरण C. छेवके यहनेः A, B.
महामात्सर्ये प्रयुक्तपरिभाषिक- शब्दानाम् अनुक्रमणिका

अश्रु (=भाग) i. ३२-३५, ३६; vi. ६, ७, ४१।
—(वृत्तविभाग) i. ५, १५; iii. २१, ३५; vi. ७, ४४, ४५, ४७; vii. ८, २, १९, २५।
—(अर्धाभाव) ii. ३।
अश्रावङ्क i. १५; vi. ४; vii. १२, १७; viii. ७, १४।
अश्रावङ्क (अर्धाभाव) ii. ५; iii. १४, १५; v. ४२; vi ४१; viii. ४।
—(५) vii. ३।
—रमण iii. २६।
—कोटि iii. २५, ३६।
—गुण iii. ५, ४४।
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—चापगुण vi. ६।
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Homage to God Śiva:

1. I bow to God Śambhu who bears on His forehead a digit of the Moon illuminating all directions by its rays, to Him whose feet are adored by the gods and who is the source of all knowledge.

Homage to planets and stars:

2. Glorious are the rays of the Sun which make the lotus blossom forth, (and those) of the Moon whose beauty is like that of the damsel’s face, (as also are) the long and clear rays of the stars including Jupiter; so also is the lustre of Mars, Mercury, Saturn, and Venus.

A benedictory stanza in appreciation of the Āryabhaṭīya and the pupils of Āryabhaṭa I:

3. May the accurate Āśmaka-tantra (āśmakaṁ sphuṭa-tantram), which has been acquired by penance, live long in the world for its excellent qualities. May also the pupils of (Ārya)-bhaṭa, who are free from sins and have conquered the enemies of passions, live long.

The āśmakaṁ sphuṭa-tantram (“the accurate Āśmaka-tantra”), according to the commentators Govinda Svāmī and Parameśvara, is the Āryabhaṭīya of Āryabhaṭa I (born 476 A.D.). Govinda Svāmī writes:

“By this (stanza) the author exhibits the greatness of the Āryabhaṭīya, ...”

So also has said Parameśvara:

“tapobhiḥ etc. is a benediction on the Āryabhaṭa-tantra and the pupils of Āryabhaṭa.”

Exclusive references to Āryabhaṭa I and his work at several places in the present work and the name Āryabhaṭa-karma-nibandha (“a compen-
dium of the astronomical processes taught by Āryabhaṭa") given to this work by the author indeed show that āṣmakaḥ sphaṭa-tantraḥ is none else than the Āryabhaṭīya.

The word āṣmakaḥ (āṣmaka-تا) literally means "pertaining to Aṣmaka", and likewise āṣmakaḥ sphaṭa-tantraḥ means "an accurate work on astronomy written, studied, or venerated in Aṣmaka, or belonging to Aṣmaka". This seems to suggest that Āryabhaṭa I, the author of that work, belonged to the Aṣmaka country. It is noteworthy in this connection that according to Nīlakaṇṭha (1500 A.D.) he was born in that country.

Reference to the Āryabhaṭīya in the above stanza at the beginning of this work is meant, as stated in the Prayaṇa-racanā and by Govinda Śvāmi to indicate the school to which the present work belongs.

MEAN LONGITUDE OF A PLANET

A rule for calculating the "ahargaṇa":

4-6. Add 3179 to the number of elapsed years of Śaka kings; then multiply (that sum) by 12; and then add the number of months elapsed (since the beginning of Caitra). Put down the result at two places. At one place multiply (that) by the number of intercalary months in a yuga and divide by the number of solar months in a yuga; and add the resulting intercalary months (omitting the fraction of a month) to the result put at the other place. Multiply the tsum by 30 and then add the number of lunar days (tīhīs) elapsed (since the beginning of the current month). Set down the result (i.e., the sum obtained) at two places. At one place multiply that by the number of omitted lunar days (in a yuga) and divide by the number of lunar days (in a yuga), and subtract the resulting omitted lunar days (neglecting the fraction of a day) from the result set down at the other place. The result (thus obtained) is the number of (mean) civil days elapsed since the beginning of Kali-yuga (at mean sunrise at Laṅkā on the given lunar day). These

1 See vs. 26 of Chapter VIII.
2 For the Aṣmaka country, see Part I, Chapter 2.
3 See Nīlakaṇṭha's comm. on A, ii. 1.
days are said to have commenced with Friday and at sunrise (at Laṅkā).¹

The above rule tells us how to determine the number of mean civil days elapsed at mean sunrise at Laṅkā on the given lunar day (tithi) since the beginning of Kaliyuga (when all the planets were in conjunction at the first point of the asterism Aśvini). According to Āryabhaṭa I and Bhāskara I, the duration of Kaliyuga is 10,80,000 years and it began on Friday, February 18, B.C. 3102, at sunrise at Laṅkā² in the beginning of the month Caitra. The Śaka Era, which is usually used in Hindu astronomy for reckoning the years, commenced 3179 years after the beginning of Kaliyuga. Caitra is the first month of the year. The months in Hindu astronomy are reckoned from one new moon to the next.

The yuga is a period of 43,20,000 years. At the beginning and end of a yuga the planets together with the Moon’s apogee and ascending node are supposed to be in general conjunction. The number of intercalary months in a yuga denotes the excess of the number of lunar months in a yuga over the number of solar months in a yuga. The number of omitted lunar days in a yuga is equal to the number of lunar days in a yuga minus the number of civil days in a yuga. The number of intercalary months, omitted lunar days, etc., in a yuga are given in the seventh chapter³.

In the rule stated above, the given true lunar month is treated as a mean lunar month and the given true lunar day is treated as a mean lunar day. The following is an explanation of the above rule:

\[
\begin{array}{cccc}
\end{array}
\]

Fig. 1

Let K denote the beginning of Kaliyuga; AA', the current mean lunar month; L, the beginning of the current mean lunar day; and s, the mean sunrise on that day. Also let S denote the beginning of the corresponding mean solar month⁴; and s', the beginning of the mean solar day

¹ The same rule occurs also in LBh, i. 4-8 and TS, i. 23-26 (i). For other similar rules, see SūSi, i. 47-50; BrŚpSi, i. 29-30, 34 (i); ŚiDVṛ, I, i. 15-17; MSi, i. 21-22; ŚiŚe, ii. 15-17; ŚiŚi, I, i (c), 1-3; ŚiŚā, i. 44-47.

² Laṅkā is a hypothetical place where the Hindu prime meridian (“the meridian of Ujjain”) intersects the equator.

³ See verses 1-8.

⁴ That is to say, if A is the beginning of the \( t \)th mean lunar month, then S is the beginning of the \( t \)th mean solar month.
corresponding to the current mean lunar day, so that the number of mean solar days between $S$ and $s'$ is equal to the number of mean lunar days between $A$ and $L$.

Adding 3179 to the number of elapsed years of the Śaka Era, we obtain the number of solar years elapsed since the beginning of Kaliyuga. Multiplying that sum by 12 and adding to the product the number of months elapsed since the beginning of Caitra, we get the number of mean solar months elapsed since the beginning of Kaliyuga. This number is equal to the number of mean solar months lying between $K$ and $S$. (See Fig. 1.) Let us denote it by $M$. When we multiply $M$ by the number of intercalary months in a $yuga$ and divide by the number of solar months in a $yuga$, we obtain the number of mean intercalary months corresponding to $M$ mean solar months. This number is, in general, made up of a whole number and a fraction. The fraction evidently denotes the fraction of a mean lunar month lying between $A$ and $S$.\(^1\) When the whole number of mean intercalary months is added to $M$, we get the number of mean lunar months lying between $K$ and $A$.\(^2\) When we multiply that by 30 and add to the product the number of lunar days ($ittis$) elapsed since the beginning of the current lunar month, we get the number of mean lunar days lying between $K$ and $L$. Let us denote this number by $T$. When we multiply $T$ by the number of omitted lunar days in a $yuga$ and divide by the number of lunar days in a $yuga$, we get the number of mean omitted lunar days corresponding to $T$ mean lunar days. This also, in general, consists of a whole number and a fraction. The fraction evidently denotes the part of a mean civil day lying between $L$ and $s$.\(^3\) When the whole number of mean omitted lunar days is subtracted from $T$, we get the number of mean civil days lying between $K$ and $s$.\(^4\) This is, in general, the number of mean civil days elapsed at mean sunrise at Laṅkā on the given lunar day since the beginning of Kaliyuga. This number is known as "ahargaṇa" (literally meaning "a collection of days"). In the above passage, Bhāskara I has called it by the synonym $aḥnāṁ ničayaḥ$.

The mean lunar day ($mahāyama-tiṣṭhi$) may, however, differ from a true lunar day ($spaṭṭa-tiṣṭhi$) by one, so that the $ahargaṇa$ obtained by the

\(^1\) See Śiśi, II, iv. 16.

\(^2\) If we add the whole number of mean intercalary months as also the fraction, we shall get the mean lunar days lying between $K$ and $S$.

\(^3\) See Śiśi, II, iv. 18 (i).

\(^4\) If we subtract the whole number of mean omitted lunar days as also the fraction, we shall get the mean civil days lying between $K$ and $L$. 
above process may sometimes be in excess or defect by one. To test whether the ahargaṇa (obtained by the above process) is correct, it is divided by seven and the remainder counted with Friday. If this leads to the day of calculation, the ahargaṇa is correct; if that leads to the preceding day, the ahargaṇa is in defect; and if that leads to the succeeding day, the ahargaṇa is in excess. When the ahargaṇa is found to be in defect, it is increased by one; when it is found to be in excess, it is diminished by one.

Similarly, when a true intercalary month has recently occurred prior to the given lunar month or is about to occur thereafter, the true lunar month may differ from the mean lunar month by one. When a true intercalary month has occurred prior to the given month and the intercalary fraction amounts to one month approximately, then the whole number of mean intercalary months obtained in the above process is increased by one. When no intercalary month has occurred prior to the given month but the intercalary fraction is small enough, the whole number of mean intercalary months obtained in the above process in diminished by one.

The word tithi in verse 4 stands for 30. It is generally used to denote the number 15.

An alternative rule:

7. Or, multiply the number of (solar) months elapsed (since the beginning of Kaliyuga) by the number of lunar months (in a yuga) and divide by the number of solar months (in a yuga). Reduce the quotient to days (and add the number of lunar days elapsed since the beginning of the current lunar month); then multiply by the number of civil days (in a yuga) and divide by the number of lunar days (in a yuga); the quotient denotes the ahargaṇa.

The number of solar months elapsed since the beginning of Kaliyuga is equal to the number of mean solar months lying between K and S.

---

1 "If the current lunar month is preceded by an intercalary month, then that intercalary month should also be treated as a lunar month." (Paramēśvara).

2 Cf. SiŚi, i (f). 3.

3 The same rule occurs also in BrSpŚi, xiii. 18 and SiŚe, ii. 3.
(See Fig. 1.) Let us denote this number by $M$, as before. When we multiply $M$ by the number of lunar months in a yuga, and divide by the number of solar months in a yuga, we obtain the number of mean lunar months corresponding to $M$ mean solar days. This number is in general, made up of a whole number and a fraction. The whole, number, which is the quotient of the division, denotes the number of mean lunar months lying between K and A. Multiplying this by 30 and adding to it the number of lunar days elapsed since the beginning of the current month, we get the number of mean lunar days lying between K and L. Let us denote this number by $T$ as before. When we multiply $T$ by the number of civil days in a yuga and divide by the number of lunar days in a yuga, we get the number of mean civil days corresponding to $T$ mean lunar days. If this number be a whole number, then it denotes the number of mean civil days lying between K and s and is therefore the ahargaṇa. (This case will occur when L and s coincide). If that number is made up of a whole number and a fraction, then the whole number as increased by one will be the ahargaṇa. This addition of one is not mentioned in the above stanza. It is stated later in verse 40.\(^1\)

Statement of the proportion used in finding the mean longitude of a planet:

8. If from the civil days (corresponding to a yuga) we get the tabulated revolutions of a planet, how many of those (revolutions) will we get from the civil days elapsed since the beginning of Kaliyuga? Thus (i.e., by applying this proportion) are obtained the revolutions (performed by the planet), and then successively the signs, degrees, minutes, seconds, and thirds (of the planet’s mean longitude).\(^2\)

\(^1\) "This ahargaṇa has sometimes to be increased by one as the author will say later." (Parameśvara). So also says Govinda Svāmī. See also \textit{BrSpSi}, xiii. 18 and \textit{SiŚe}, ii. 3.

\(^2\) Cf. \textit{SuŚi}, i. 53; \textit{BrSpSi}, i. 31; \textit{LBk}, i. 15-17 (i); \textit{ŚiDVṛ}, i. 21 (i); \textit{MSi}, i. 25 (i); \textit{SiŚe}, ii. 14; \textit{SiŚi}, i. (c). 4; \textit{SiŚā}, i. 53.
DERIVATION OF MEAN LONGITUDE

That is to say,

mean longitude of a planet in revolutions

\[ \frac{(\text{revolution-number of the planet}) \times (\text{aharga})}{\text{civil days in a yuga}} \]

A rule for deriving the mean longitude of a planet from that of the Sun:

9. Reduce the Sun's mean longitude (given in terms of signs, degrees, and minutes) together with the years elapsed (treated as revolutions) to minutes of arc. Multiply them by the planet's own revolution-number stated in the Gitikā and divide (the product) by the number of (solar) years in a yuga. The result, say (the learned), is the planet's mean longitude in terms of minutes.

That is to say,

mean longitude of a planet in terms of minutes

\[ \frac{(\text{Sun's mean longitude in revolutions etc. reduced to minutes}) \times (\text{planet's revolution-number})}{\text{Sun's revolution-number}} \]

A rule for deriving the mean longitude of a planet from the mean longitude of the Moon or a planet or the ucca of a planet.

10. The (mean) longitude of the Moon, the planet, or the ucca (whichever is known) together with the revolutions performed should be reduced to minutes. The resulting minutes should then be multiplied by the revolution-number of the desired planet and (the product obtained should be) divided by the revolution-number of that (known) planet. The result is (the mean longitude of the desired planet) in terms of minutes.\(^1\)

---

\(^1\) This is the name of the first chapter of the Āryabhaṭīya.

\(^2\) This rule occurs also in BrSpSi, xiii. 27; ŚiDVṛ, I, i. 30 (i); ŚiŚe, ii. 25-26: ŚiŚi, I, i (c). 14 (i).
That is to say

\[
\text{mean longitude of the desired planet in minutes} = \frac{(\text{mean longitude of the known planet in revolutions, etc., reduced to minutes}) \times (\text{revolution-number of the desired planet})}{\text{revolution-number of the known planet}}.
\]

This rule and the previous one are based on the following principle. If there are two planets \(P\) and \(Q\), then

\[
\text{revolution-number of } P : \text{revolution-number of } Q
\]

\[
: : (\text{mean longitude of } P \text{ in revolutions etc.}) : (\text{mean longitude of } Q \text{ in revolutions etc.}).
\]

Alternative rules for deriving the mean longitude of the Moon from that of the Sun and vice versa:

11. Or, multiply the \textit{ahargaṇa} by the number of intercalary months in a \textit{yuga} and divide (the product) by the number of civil days (in a \textit{yuga}) : the result is in terms of revolutions, etc. Add that to thirteen times the mean longitude of the Sun. (This is the process to obtain the mean longitude of the Moon.)

12. Or, subtract the result obtained (in revolutions etc.) from the mean longitude of the Moon and take one-thirteenth of the remainder : this is stated to be the mean longitude of the Sun by the mathematicians whose intellect has been awakened by the grace of the teacher.

The following is the rationale:

We know that

\[
\begin{align*}
\text{intercalary months in a } \textit{yuga} & = \text{ lunar months in a } \textit{yuga} - \text{ solar months in a } \textit{yuga}. \\
\text{But lunar months in a } \textit{yuga} & = \text{ Moon’s revolution-number } - \text{ Sun’s revolution-number}; \\
\text{and solar months in a } \textit{yuga} & = 12 \text{ (Sun’s revolution number)}. 
\end{align*}
\]

\[1\text{ This rule is found also in } BrSpSi, \text{ xiii. 33; } ŚiDVṛ, \text{ I, i. 24 (ii); SiŚe, ii. 19.}\]
Therefore, we have

intercalary months in a yuga

= Moon’s revolution-number — 13 (Sun’s revolution-number),

giving

Moon’s revolution-number

= intercalary months in a yuga + 13 (Sun’s revolution-number).

Multiplying the two sides of this equation by the ahargana and dividing by the number of civil days in a yuga, we get

mean longitude of the Moon

= \frac{(intercalary months in a yuga) \times (ahargana)}{civil days in a yuga} \text{ revolutions}

+ 13 (Sun’s mean longitude). \quad \ldots \quad (1)

And rearranging this equation, we have

mean longitude of the Sun = \frac{1}{13}\left\{\frac{\text{mean longitude of the Moon}}{(intercalary months in a yuga) \times ahargana} \text{ revolutions}\right\}.

\ldots \quad (2)

A rule for calculating the mean longitudes of the Sun and the Moon without making use of the ahargana:

13-19. For one (desirous of) calculating the mean longitudes of the Moon and the Sun without the use of the ahargana, the following method is stated:

Reduce the years (elapsed since the beginning of Kaliyuga) to months, and add to them the elapsed months (of the current year). Then multiply that (sum) by 30, and add the product to the number of (lunar) days elapsed since the beginning of the current month. Multiply that (sum) by the number of intercalary months (in a yuga) and divide by the number of solar months in a yuga reduced to days: the quotient denotes the number of intercalary months (elapsed). Delete (or rub out) the divisor
and divide the remainder (called *adhimāsāsēsā*, i.e., the residue of the intercalary months) by the number of lunar months (in a *yuga*): thus are obtained degrees, minutes, seconds, and thirds. Then multiply the (complete) intercalary months elapsed by 30 and to the product add the number of solar days (elapsed since the beginning of Kāliyuga); then multiply that (sum) by the number of omitted lunar days in a *yuga* and divide by the number of lunar days (in a *yuga*): the remainder obtained is (the *avamaśēsā*, i.e., the residue of the omitted lunar days) called āhnika. Then multiply the *avamaśēsā* by the number of intercalary months (in a *yuga*) and divide by the number of civil days (in a *yuga*). Add the resulting quotient to the *adhimāsāsēsā* and then apply the process stated above (i.e., divide by the number of lunar months in a *yuga*: the result is in degrees, minutes, etc. This is the total *adhimāsāsēsā*). Next multiply the *avamaśēsā* called āhnika by 60 and divide by the number of civil days in a *yuga*: the result is in minutes, seconds, and thirds respectively. The number of months elapsed (since the beginning of Caitra) are to be taken as signs, and the number of lunar days elapsed (of the current month) as degrees. (The sum of these signs and degrees and the minutes, seconds, etc., corresponding to the *avamaśēsā* is the *grahatānu*). From thirteen times and from one time that (*grahatānu*) severally subtract the degrees, minutes, etc. corresponding to the (total) *adhimāsāsēsā*: the remainders (thus obtained) are stated by the wise astronomers to be the mean longitudes of the Moon and and Sun (respectively) conforming to the teachings of (Ārya)bhaṭa.

The process described in the above rule is not in proper sequence. The direction given in verse 15 ought to have been after verse 17. Stated in proper sequence, the rule would be:

---

1 This rule occurs also in *BrSpSi*, xiii. 20-22; *KK* (Sengupta), i. 11-12; and *SiSe*, ii. 21-22. For similar rules, see *ŚidVṛ*, I, i. 27, 25-26; and *ŚīŚi*, I, i (c). 6-7.
“Reduce the years (elapsed since the beginning of Kaliyuga) to months, and add to them the elapsed months (of the current year). Then multiply the sum by 30, and add the product to the number of (lunar) days elapsed since the beginning of the current month. Multiply that sum by the number of intercalary months (in a yuga) and divide by the number of solar months in a yuga reduced to days: the quotient denotes the number of intercalary months (elapsed). (The remainder is the adhimāsaśeṣa). Multiply the (complete) intercalary months (thus obtained) by 30 and to the product add the number of solar days (elapsed since the beginning of Kaliyuga) \(^1\); then multiply that (sum) by the number of omitted lunar days in a yuga and divide by the number of lunar days (in a yuga); the remainder obtained is (the avamaśeṣa) called āhnika. Then multiply the avamaśeṣa (called āhnika) by the number of intercalary months (in a yuga) and divide by the number of civil days (in a yuga). Add the resulting quotient to the adhimāsaśeṣa and divide the sum by the number of lunar months in a yuga: this gives degrees, etc. (This is the total adhimāsaśeṣa.) Next multiply (again) the avamaśeṣa called āhnika by 60 and divide by the number of civil days in a yuga: the result is in minutes, seconds, and thirds, etc. The number of months elapsed (since the beginning of Caitra) are to be taken as signs and the number of lunar days elapsed (of the current month) as degrees. (The sum of these signs and degrees, and the minutes, seconds, etc. corresponding to the avamaśeṣa is the grahatanu). From thirteen times and from one time that (grahatanu) severally subtract the degrees, minutes, etc. corresponding to the (total) adhimāsaśeṣa: the remainders (thus obtained) are stated by the wise astronomers to be the mean longitudes of the Moon and the Sun (respectively) conforming to the teachings of (Ārya)bhaṭa.”

The following is the rationale of the above rule:

The fraction of the intercalary month (obtained in the rule)

\[
= \frac{adhimāsaśeṣa}{\text{solar days in a yuga}}, \text{ in mean lunar months.}
\]

\(^1\) By the number of solar days here is meant the number obtained above by ‘reducing the years elapsed since the beginning of Kaliyuga to months, then adding to them the number of months elapsed since the beginning of the current year, then multiplying the sum by 30, and then adding to the product thus obtained the “number of lunar days elapsed of the current month”.

MEAN LONGITUDE OF A PLANET

\[ \frac{adhimāsaśeṣa}{\text{lunar days in a yuga}}, \text{ in mean solar months.} \]

(1)

The fraction of the omitted lunar day (obtained in the rule)

\[ \frac{avamaśeṣa \text{ or } âhniκa}{\text{lunar days in a yuga}}, \text{ in mean civil days.} \]

\[ \frac{avamaśeṣa}{\text{civil days in a yuga}}, \text{ in mean lunar days.} \]

\[ \frac{avamaśeṣa \times 60}{\text{civil days in a yuga}}, \text{ in mean lunar } ghātis. \]

(2)

The fraction of the intercalary month corresponding to the above fraction of the omitted lunar day

\[ \frac{\text{(intercalary months in a yuga)} \times (avamaśeṣa)}{( \text{lunar days in a yuga}) \times (\text{civil days in a yuga})}, \text{ in mean solar months.} \]

(3)

Adding (1) and (3) and multiplying by 30, the total fraction of the intercalary month

\[ \left\{ \frac{adhimāsaśeṣa}{\text{lunar months in a yuga}} + \frac{\text{(intercalary months in a yuga) } \times (avamaśeṣa)}{( \text{lunar months in a yuga}) \times (\text{civil days in a yuga})} \right\}, \text{ in mean solar days.} \]

(4)

Suppose that \( m \) lunar months and \( d \) lunar days have elapsed since the beginning of Caitra. Then, treating them as mean lunar months and mean lunar days, \( m \) months and \( d \) days denote the time elapsed since the beginning of mean Caitra up to the beginning of the current lunar day (treated as mean lunar day). As (2) is the interval, in mean lunar \( ghātis, \) between the beginning of the current lunar day and the mean sunrise on that day, therefore

\[ m \text{ months } + d \text{ days } + (2) \]
denotes the time in mean lunar months, days, and \( \text{ghaṭīs} \)\(^1\) elapsed since the beginning of mean Caitra up to the mean sunrise on the current lunar day. Likewise
\[
m \text{ months} + d \text{ days} + (2) - (4)
\]
denotes the time in mean solar months, days, \( \text{ghaṭīs} \), etc. elapsed since the beginning of the current mean solar year up to the mean sunrise on the current lunar day. \(^2\)

Let \( M, D, G, V, \) and \( P \) denote respectively the mean solar months, mean solar days, mean solar \( \text{ghaṭīs} \), mean solar \( \text{vighaṭīs} \), and mean solar \( \text{pravighaṭīs} \) elapsed since the beginning of the current mean solar year up to the mean sunrise on the current lunar day. Then evidently

mean longitude of the Sun
\[
= M \text{ signs, } D \text{ degrees, } G \text{ minutes, } V \text{ seconds, and } P \text{ thirds.}
\]
\[
= (m \text{ signs and } d \text{ degrees}) + [\text{minutes, seconds, etc. corresponding to } (2)] - [\text{degrees, minutes, etc. corresponding to } (4)];
\]

and mean longitude of the Moon
\[
= 13 [m \text{ signs and } d \text{ degrees} + (\text{minutes, seconds, etc. corresponding to } (2)) - [\text{degrees, minutes, etc. corresponding to } (4)],
\]
because
\[
(1/12) (\text{mean longitude of the Moon} - \text{mean longitude of the Sun})
\]
\[
= m \text{ signs} + d \text{ degrees} + [\text{minutes, seconds, etc. corresponding to } (2)].\(^3\)
\]

\(^1\) 1 hour = \(2\frac{1}{2} \text{ ghaṭīs}\).
\(^2\) Because (4) is equal to
\{ fraction of a lunar month between the beginning of Caitra and the beginning of the current mean solar year \} + \{ fraction of an intercalary month corresponding to the \text{tithis} \} elapsed up to the beginning of the current mean lunar day since the beginning of Caitra \} + \{ fraction of an intercalary month corresponding to the \text{avamaśeṣa}, i.e., the lunar portion between the beginning of the current lunar date and the following sunrise \}.

\(^3\) This equality is based on the fact that the left hand side denotes the mean lunar date \( \text{(madhyama-tithi)} \). \text{Vide infra, iv. 31.}
It must be noted that, unless otherwise stated, the mean lunar day and the mean sunrise, etc., correspond to Laṅkā, and that 'the mean longitude of a planet' means 'the mean longitude for mean sunrise at Laṅkā'.

Śripati gives in addition to the above rule, the following two interesting rules also. It may be pointed out that Śripati uses a period of 4,32,00,00,000 years called a kalpa in place of a yuga.

Rule 1.

Moon's longitude = Sun's longitude + 12 \( \left\{ \text{tithis elapsed up to the} \right\} \) 

\[ \text{beginning of the current tithi} + \frac{\text{avamaśeṣa}}{\text{civil days in a kalpa}} \] 

degrees.

Sun's longitude = Moon's longitude - 12 \( \left\{ \text{tithis elapsed up to the} \right\} \) 

\[ \text{beginning of the current tithi} + \frac{\text{avamaśeṣa}}{\text{civil days in a kalpa}} \] 

degrees.

\text{Cf. SiŚe, ii, 20.}

Rule 2.

Moon's longitude = Sun's longitude + 12 \( \left\{ \text{tithis elapsed up to the} \right\} \) 

\[ \text{beginning of the current tithi) degrees + (Moon's daily motion in degrees} \] 

\[ \text{Sun's daily motion in degrees} \times \frac{\text{avamaśeṣa}}{\text{lunar days in a kalpa}} \]

Sun's longitude = Moon's longitude - 12 \( \left\{ \text{tithis elapsed up to the} \right\} \) 

\[ \text{beginning of the current tithi) degrees} \times \frac{\text{avamaśeṣa}}{\text{lunar days in a kalpa}} \] 

\[ \text{\times (Moon's} \] 

daily motion in degrees - Sun's daily motion in degrees \}

\text{Cf. SiŚe, ii, 24.}

\(^1\) Vide supra, p. 3 (footnote).
Proof:

Moon’s longitude at sunrise — Sun’s longitude at sunrise
\[ \frac{12}{tithi \ at \ sunrise} \]
\[ = tithi \ at \ the \ beginning \ of \ the \ current \ tithi + tithi \ corresponding \ to \ \text{avamaśeṣa} \]
\[ = tithi \ at \ the \ beginning \ of \ the \ current \ tithi \]
\[ + \frac{\text{Moon’s daily motion in degrees} - \text{Sun’s daily motion in degrees}}{12} \]
\[ \times \frac{\text{avamaśeṣa}}{\text{lunar days in a kalpa}} \]

because tithi corresponding to 1 civil day
\[ = \frac{\text{Moon’s daily motion in degrees} - \text{Sun’s daily motion in degrees}}{12\circ} \]

Another rule for finding the mean longitude of a planet:

20. Divide the (yojanas of the) circumference of the sky by the number of civil days (in a yuga): the result is the number of yojanas traversed (by a planet) per day. By those (yojanas) multiply the ahargaṇa and then divide (the product) by the length (in yojanas) of the own orbit of the planet. From that are obtained the revolutions, signs, etc. (of the mean longitude of the planet).

From stanza 8 above, we have

mean longitude of a planet
\[ = \frac{\text{(revolution-number of the planet) } \times \text{ (ahargaṇa) \times civil days in a yuga}}{ \text{circumference of the sky}^1 \text{ (revolutions-number of the planet)}} \]

But from vii. 20

length of a planet’s orbit
\[ = \frac{\text{circumference of the sky}^1}{\text{revolution-number of the planet}} \]

1 For the length of the circumference of the sky, see vii. 20.
so that

\[
\text{revolution-number of a planet} = \frac{\text{circumference of the sky}}{\text{length of the planet's orbit}}.
\]

Hence we have

\[
\text{mean longitude of a planet} = \frac{(\text{circumference of the sky}) \times \text{aharga}\
a (\text{civil days in a yuga}) \times (\text{length of the planet's orbit})}
\]

Introduction to the topic discussed in the succeeding eighteen stanzas:

21. After a careful study of the ocean of the Āśmakiya śāstras (śāstrāṇavam āśmakiyāṁ) I reveal the planetary procedure, the secret there, (hitherto) unnoticed by the other followers of the Āśmakiya (āśmakiyāḥ) by means of simplified rules (laghu-tantra).

Āśmakiyaṁ (literally meaning ‘a book written by one born in or belonging to the Āsmaka country’) refers to the Āśmaka-tantra (i.e., Aryabhaṭīya) mentioned in stanza 3 above. āśmakiyāḥ means ‘the followers of the Āśmakiya’, or, as the commentator Parameśvara says, ‘the pupils (or followers) of Āryabhaṭa I’.

The stanza under consideration shows that Bhāskara I, the author of the present work, was the earliest Āśmakiya (‘follower of Āryabhaṭa I’) to give the method of the prayāyda-śuddhi stated in the next eighteen stanzas. The method was, however, not invented by him. In his commentary on the Aryabhaṭīya he himself writes that it was already in use amongst the followers of the Romaka-siddhānta.² It occurs in the Brāhma-sphuṭa-siddhānta also.

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¹ “āśmakiya āryabhaṭaśiṣyāḥ” (Parameśvara)
² See comm. on A, iii. 10.
A rule for determining the number of mean lunar days lying between the beginning of mean Caitra and the beginning of the mean solar year:

22. Always having ascertained the number of years (elapsed since the beginning of Kaliyuga), multiply them by 11 and by 389/6000 (separately). Add the two results, and divide the sum (thus obtained) by 30. The quotient of division denotes (the mean intercalary) months, and the remainder (the mean intercalary) days.

The mean intercalary days obtained from this rule are equal to the number of mean lunar days lying between the beginning of mean Caitra and the beginning of the mean solar year.

The number of mean intercalary days in a mean solar year is equal to 11 + 389/6000. Hence the above rule.

A rule for finding the number of mean lunar days elapsed at the beginning of the mean solar year since the occurrence of a mean omitted lunar day:

23. Multiply (the number of years elapsed since the beginning of Kaliyuga) by 29 as divided by 36 (i.e., by 29/36). Again multiply the same (number of years) by 43 and divide by 72000. The sum of the two quotients gives the (residual mean omitted lunar) days. (Multiply the remainder of the first division by 2000, increase the product by the remainder of the second division, and then) divide (the sum) by 1125: then are obtained (the mean lunar) days (which have elapsed at the beginning of the mean solar year since the occurrence of a mean omitted lunar day).

The number of mean omitted lunar days in a mean solar year is 5 + 29/36 + 43/72000; and the number of mean lunar days between two successive mean omitted lunar days is approximately 64. Hence the above rule.
A rule for finding the number of mean lunar days elapsed at the beginning of mean Caitra since the occurrence of a mean omitted lunar day:

24. From them (i.e., from the mean lunar days elapsed at the beginning of the mean solar year since the occurrence of a mean omitted lunar day) subtract the mean intercalary days (obtained in stanza 22 above): the remainder (obtained) is the time (in terms of mean lunar days) elapsed (at the commencement of mean Caitra) since the fall of a (mean) omitted lunar day. In case the subtraction is not possible, add 64 (to the minuend) and then from the sum perform the subtraction.

The subtraction is not possible when a mean omitted lunar day happens to fall between the beginning of mean Caitra and the beginning of the mean solar year. In such a case the omitted lunar days (obtained in stanza 23) should be diminished by one.

A rule for finding the lord of the year:

25-26(i). Divide the sum of the months¹ (which have elapsed at the beginning of the mean solar year since the beginning of Kaliyuga) and the (corresponding complete mean) intercalary months (obtained in stanza 22) by seven; and multiply the remainder by 30. Now we say what is to be subtracted from this: Divide the number of years elapsed since the beginning of Kaliyuga by seven and multiply the remainder (of the division) by five, add this product to the number of (residual mean) omitted lunar days (obtained in stanza 23) and divide the sum by seven: the remainder (of this division is the quantity to be subtracted). (Divide the difference of this quantity and the one obtained previously, by seven). The remainder increased by one counted with Friday gives the lord of the year (i.e., the planet presiding over the first day of Caitra). So has been stated by the learned.

¹ These months are mean solar months and are obtained by multiplying the years elapsed since the beginning of Kaliyuga by twelve.
The number of mean civil days elapsed at the beginning of the mean solar year

\[= 12 \times 30 \times (\text{solar years elapsed}) + \left(11 + \frac{389}{6000}\right) \times (\text{solar years elapsed}) - \left(\frac{5+29}{36+43/72000}\right) \times (\text{solar years elapsed})\]

\[= 30 \times (\text{solar months elapsed} + \text{mean intercalary months obtained in stanza 22}) + \text{mean intercalary days obtained in stanza 22} - (5 \times \text{solar years elapsed} + \text{residual mean omitted lunar days obtained in stanza 23}).\]

Therefore, the number of mean civil days elapsed on the first day of mean Caitra (or true Caitra)\(^1\)

\[= 30 \times (\text{solar months elapsed} + \text{mean intercalary months obtained in stanza 22}) - (5 \times \text{solar years elapsed} + \text{residual mean omitted lunar days obtained in stanza 23}).\]

When these civil days are increased by one and divided by seven, the remainder of the division counted with Friday gives the day on which Caitra begins. In the above rule the author has avoided big numbers by dividing by seven at every stage. His rule is therefore easy to apply in practice.

A rule for finding the number of mean omitted lunar days occurring since the fall of the mean omitted lunar day just before the beginning of mean Caitra:

28(ii). Increase the number of (lunar) days (elapsed since the beginning of Caitra) by the number of (mean lunar) days elapsed (at the beginning of Caitra) since the fall of a mean omitted lunar day, and divide that (sum) by 64: the quotient gives the number of (mean) omitted lunar days (which have occurred since the mean omitted lunar day occurring before the beginning of Caitra):

A rule for finding the number of mean lunar days lying between the beginning of mean Caitra and the beginning of the mean solar year (called "the subtractive"):

\(^1\) The first day of true Caitra may sometimes differ from that of mean Caitra by one day.
27-28. Multiply the number of years (elapsed since the beginning of Kaliyuga) by 149 and then divide by 576: the quotient is in terms of days. Add these days to ten times the number of years (elapsed): thus are obtained the so called raviya days. To the raviya days add the (residual mean) omitted lunar days obtained above (in stanza 23). From the sum subtract the (complete mean) intercalary months (obtained in stanza 22) as multiplied by 30. Whatever is obtained as the remainder is “the subtractive” for the (current) year. When the subtrahend is greater, then the difference is prescribed as “the additive”.

Let \( Y \) denote the number of years elapsed since the beginning of Kaliyuga.

The number of mean civil days in one mean solar year

\[
= 365 + \frac{149}{576}.
\]

Therefore, the number of mean civil days in \( Y \) mean solar years

\[
= 365Y + \left( \frac{149}{576} \right) Y
\]

\[
= 365Y + \text{residual mean civil days.} \quad (1)
\]

The number of mean omitted lunar days in \( Y \) mean solar years

\[
= (5 + 29/36 + 43/72000)Y
\]

\[
= 5Y + \text{residual mean omitted lunar days.} \quad (2)
\]

Adding (1) and (2), the number of mean lunar days in \( Y \) mean solar years

\[
= 370Y + \text{residual mean civil days}
\]

\[
+ \text{residual mean omitted lunar days.} \quad (3)
\]

From (3) subtracting 360\( Y \) (i.e., the number of mean solar days in \( Y \) years), the number of mean intercalary days in \( Y \) solar years

\[
= 10Y + \text{residual mean civil days}
\]

\[
+ \text{residual mean omitted lunar days.} \quad (4)
\]

Subtracting the complete mean intercalary months (elapsed since the beginning of Kaliyuga as reduced to days) from (4), we get the residual mean intercalary days. These are equal to the mean lunar days lying between the
beginning of mean Caitra and the beginning of the mean solar year, and constitute the so called "subtractive."

The definition of the so called *grahatanu* for the Moon, Mars, Jupiter, and Saturn:

29. The number of years elapsed (since the commencement of Kaliyuga) multiplied by 360 is always called *grahatanu*. The (mean) longitudes (reduced to degrees) of the planets (Sun, Mercury, and Venus) together with the *grahatanu* are called *dhruvaka* by the learned.

The term *grahatanu* denotes the number of mean solar days elapsed at the beginning of the mean solar year since the beginning of Kaliyuga. This *grahatanu*, as remarks the commentator Parameśvara, is really a part of the *grahatanu*.

The *dhruvaka* (i.e., complete *grahatanu*) denotes the number of mean solar days elapsed on the given lunar day since the beginning of Kaliyuga. The above *dhruvaka*, or *grahatanu*, is defined for the Moon, Mars, Jupiter, and Saturn only; that for the Sun, Mercury, and Venus is defined in the next stanza.

The *grahatanu* for the Sun, Mercury, and Venus:

30. Diminish the (lunar) days elapsed since the beginning of Caitra by the corresponding complete omitted lunar days (obtained in the second half of stanza 26) and divide (the difference) by seven: the remainder (of the division) counted with the first day of Caitra is said to give the (current) day. From that, the "subtractive" for the year (obtained in stanzas 27-28) should also be subtracted. (But it must be remembered that) the minuend of this subtraction is the difference of the previous subtraction and not the other (i.e., not the remainder of the division). (The remainder obtained by subtracting the "subtractive" is the *grahatanu* for the Sun, Mercury, and Venus. It denotes the number of mean civil days elapsed since the beginning of the mean solar year).

The number of mean civil days elapsed since the beginning of the mean solar year is generally known as *laghvahargaṇa* ("smaller ahargaṇa").
Rules for finding the laghvahargaṇa occur in the Brāhma-sphuṭa-siddhānta\textsuperscript{1}, the Śiṣya-dhi-vṛddhida\textsuperscript{2}, the Siddhānta-śekhara\textsuperscript{3}, and the Siddhānta-śiromāṇi\textsuperscript{4}, etc., but the process described in the above rule is slightly different from them.

A rule for finding of the mean longitudes of the Sun, Mercury, and Venus:

31. Divide the grahadeha (for the Sun) by 70: the result is in days, etc. Then multiply one-fifth of the grahadeha by 2: the result is in vighatikās\textsuperscript{5}. These (days and vighatikās) subtracted from the grahadeha are stated to be (the degrees, minutes, etc. of) the mean longitudes of the Sun, Mercury, and Venus.\textsuperscript{8}

The grahadeha is the same as grahatanu defined above. The following is the rationale of the above rule.

**Rationale 1.**

The grahadeha is in terms of mean civil days. This has to be converted into mean solar days.

The difference between civil and solar days in a yuga

\[
= 1577917500 - 1555200000
\]

\[
= 22717500 \text{ days.}
\]

Therefore, this difference per mean civil day

\[
= \frac{22717500}{1577917500} \text{ of a day}
\]

\[
= \frac{1}{70} \text{ of a day} - \frac{2}{5} \text{ of a vighatikā approx.}
\]

\textsuperscript{1} i. 42-43.

\textsuperscript{2} I, i. 37.

\textsuperscript{3} ii. 40-41(i).

\textsuperscript{4} I, i(e). 12-13.

\textsuperscript{5} The same rule occurs also in ŚiDVt, I, i. 39 and in GL, i. 10(i). Similar rules occur in BrSpSi, i. 44; Msi, i. 26; SiŚe, ii. 42, 43; SiŚi, I, i(d). 15; SiŚā, i. 105; KPr, i. 4; KKaU, i. 16; KKu, i. 7; and SK, i. 6 (i).
Hence the number of mean solar days corresponding to the desired grahadeha

\[ (1 - 1/70) \times \text{grahadeha days} \]

\[ - (2/5) \times (\text{grahadeha}) \text{ vighati każs}. \]

Consequently, the mean longitude of the Sun, Mercury, or Venus

\[ (1 - 1/70) \times (\text{grahadeha}) \text{ degrees} \]

\[ - (2/5) \times (\text{grahadeha}) \text{ seconds}. \]

Rationale II.

The mean daily motion of the Sun

\[ \frac{4320000}{1577917500} \text{ of a revolution} \]

\[ = \frac{4320000 \times 12 \times 30}{1577917500} \text{ of a degree} \]

\[ = (1 - 3029/210389) \text{ of a degree} \]

\[ - (1 - 1/70) \text{ of a degree} - \frac{1641 \times 60 \times 60}{210389 \times 70} \text{ of a second} \]

\[ = (1 - 1/70) \text{ of a degree} - 2/5 \text{ of a second approx.} \]

Hence the rule.

A rule for finding the mean longitude of the Moon:

32. Multiply the grahatanu for the Moon by 83 (lit. \(9^2 + 2\)) and divide by 225; the result is in terms of degrees, etc. From that subtract the seconds obtained by multiplying the grahatanu by 11 and dividing by 50. (Then add the remainder to thirteen times the mean longitude of the Sun as prescribed in stanza 35 below: the sum thus obtained is the mean longitude of the Moon). ¹

¹ Similar rules occur in SīDV, i. 40-41; MSi, i. 43(i); SīŚā, i. 106; KPr, i. 5; GL, i. 10 (ii); KKu, i. 8; KKau, i. 17; and SK, i. 6(ii).
MEAN LONGITUDE OF A PLANET

Rationale I.

The grahatanu for the Moon denotes the number of mean solar days elapsed since the beginning of Kaliyuga or the mean longitude of the Sun in revolutions, etc., reduced to degrees.

Since

\[
\frac{\text{mean longitude of the Moon in revolutions etc.}}{\text{mean longitude of the Sun in revolutions etc.}} = \frac{\text{revolution-number of the Moon}}{\text{revolution-number of the Sun}}
\]

\[
= \frac{57753336}{4320000}
\]

\[
= 13 + \frac{83}{225} - \frac{264}{4320000}
\]

\[
= 13 + \frac{83}{225} - \frac{11}{50 \times 60 \times 60},
\]

therefore

\[
\text{mean longitude of the Moon}
= 13 \times (\text{mean longitude of the Sun})
+ \frac{83 \times G}{225} \text{ degrees} - \frac{11 \times G}{50} \text{ seconds},
\]

where \(G\) is the grahatanu for the Moon.

Rationale II.

The mean motion of the Moon per solar day

\[
= \frac{57753336}{4320000} \text{ degrees}
\]

\[
= \left\{ 13 + \frac{83}{225} \right\} \text{ degrees} - \frac{11}{50} \text{ of a second}
\]

Therefore, the mean motion of the Moon for \(G\) solar days, i.e., the mean longitude of the Moon

\[
= \left\{ 13G + \frac{83G}{225} \right\} \text{ degrees} - \frac{11G}{50} \text{ seconds}
\]

\[
= 13 \times \text{Sun's mean longitude}
+ \frac{83G}{225} \text{ degrees} - \frac{11G}{50} \text{ seconds}.
\]
A rule for finding the mean longitude of the Moon's ascending node:

33. Divide (the *grahatanu*) by 270: these are degrees. Multiply (the *grahatanu*) by 113 and divide by 600: these are seconds. These together with one-twentieth part of the (mean) longitude of the Sun (in revolutions, etc.) constitute the (mean) longitude of the Moon's ascending node. ¹

The mean motion of the Moon's ascending node per solar day

\[
\frac{232226}{4320000} \text{ of a degree}
\]

\[
= \frac{1}{20} + \frac{1}{270} \text{ of a degree } + \frac{113}{600} \text{ of a second.}
\]

Hence the rule.

A rule for finding the mean longitude of the Moon's apogee:

34. Multiply the *grahatanu* by seven and divide by nine: these are minutes. Then multiply the *grahatanu* by 11 and divide by 60: these are seconds. Then divide the *grahatanu* by 20: these are thirds to be subtracted. These together with one-tenth of the Sun's (mean) longitude (in revolutions, etc.) constitute the (mean) longitude of the Moon's apogee:

The mean motion of the Moon's apogee per solar day

\[
\frac{488219}{4320000} \text{ of a degree}
\]

\[
= \frac{1}{10} \text{ of a degree } + \frac{7}{9} \text{ of a minute } + \frac{11}{60} \text{ of a second } - \frac{1}{20} \text{ of a third.}
\]

Hence the rule.

¹ Similar rules occur in *BrSpSt*, xxv, 35, and *ŚiDVṛ*, I, i. 52 (ii).
A rule for finding the mean longitude of the ścirocca of Venus, and also giving the additives for the ścirocca of Mercury and the Moon:

35. Multiply the grahatanu by 37 and divide by 900: these are the degrees, etc., (forming part) of the (mean) longitude of (the ścirocca of) Venus. Then divide the grahatanu by 100: these are seconds. Add to these one-third of the Sun’s (mean) longitude (in revolutions, etc.). Then subtract the whole of that (sum) from two times the Sun’s (mean) longitude. (The difference thus obtained is the mean longitude of the ścirocca of Venus). ¹

To the (mean) longitudes of (the ścirocca of) Mercury and the Moon add four times the Sun’s (mean) longitude and thirteen times the Sun’s (mean) longitude respectively. ²

The mean motion of the ścirocca of Venus per solar day

\[
\frac{7022388}{4320000}\ \text{degrees}
\]

\[
= (2-1/3-37/900) \text{ degrees} - 1/100 \text{ of a second.}
\]

Hence the rule.

A rule for finding the mean longitude of the ścirocca of Mercury:

36. Divide the grahatanu by 200: the result is in terms of signs. Then divide the grahatanu by 8: these are minutes. Then divide the grahatanu by 60: these are seconds. Adding all these (and also four times the Sun’s mean longitude as prescribed in stanza 35) is obtained the (mean) longitude of (the ścirocca of) Mercury. ³

¹ Similar rules occur in BrSpSi, xxv. 36 and SiDVr, I, i. 57 (ii).
² See stanzas 32 and 36.
³ Similar rules occur in BrSpSi, xxv. 34 and SiDVr, I, i. 50 (ii).
The mean motion of the śīghrocça of Mercury per solar day

\[ = \frac{17937020}{4320000} \text{ degrees} \]

\[ = 1/200 \text{ of a sign} + 4 \text{ degrees} + 1/8 \text{ of a minute} + 1/60 \text{ of a second.} \]

Hence the rule.

A rule for finding the mean longitude of Saturn:

37. Multiplying the grahatanu by 8 and dividing by 225 are obtained minutes; and dividing (the grahatanu) by 300 are obtained seconds. Adding these two together and increasing that (sum) by one-thirtieth of the Sun’s (mean) longitude is obtained the (mean) longitude of Saturn.¹

The mean motion of Saturn per solar day

\[ = \frac{146564}{4320000} \text{ of a degree} \]

\[ = 1/30 \text{ of a degree} + 8/225 \text{ of a minute} + 1/300 \text{ of a second.} \]

Hence the rule.

A rule for finding the mean longitude of Mars:

38. Multiply the grahatanu by two and subtract one-twentieth of itself from that; these are minutes, etc. Then divide the grahatanu by 50: these are seconds. Add these (minutes and seconds) to half the Sun’s (mean) longitude (in revolutions, etc.): the sum is the (mean) longitude of Mars.²

The mean motion of Mars per solar day

\[ = \frac{2296824}{4320000} \text{ of a degree} \]

\[ = 1/2 \text{ of a degree} + (2 - 2/20) \text{ minutes} + 1/50 \text{ of a second.} \]

Hence the rule.

¹ Similar rules occur in BrSpSi, xxv. 35 and ŚiDVṛ, I, i. 52 (i).
² Similar rules occur in BrSpSi, xxv. 33 and ŚiDVṛ, I, i. 50 (i).
A rule for finding the mean longitude of Jupiter:

39. Multiply the grahadeha by 22 and divide by 375: these are minutes, etc. Add them to one-twelfth of the Sun's (mean) longitude (in revolutions, etc.): the result is the (mean) longitude of Jupiter.¹

The mean motion of Jupiter per solar day

\[
= \frac{364224}{4320000} \text{ of a degree}
\]

\[
= 1/12 \text{ of a degree} + 22/375 \text{ of a minute.}
\]

Hence the rule.

Corrections to be applied to the mean longitudes of the Moon's apogee and ascending node, and to the ahargana:

40. Add three signs to the mean longitude of the Moon's apogee. Subtract the (mean) longitude of the Moon's ascending node from 12 signs and then add 6 signs. Also (if necessary) add one to the ahargana obtained by proportion (in stanza 7 above). So say the astronomers whose hearts are devoted to Āryabhaṭa's system of astronomy (bhāṭākāstra).

At the beginning of Kaliyuga, according to Āryabhaṭa I's system of astronomy, the mean longitude of the Moon's apogee was 3 signs and that of the Moon's ascending node 6 signs. Hence, the addition of 3 signs to the mean longitude of the Moon's apogee and of 6 signs to the mean longitude of the Moon's ascending node prescribed by the author. The longitude of the Moon's ascending node has to be subtracted from 12 signs, because the motion of the Moon's ascending node is retrograde.

The remaining chapter deals with the solution of pulverisers (kuṭṭākāra) having reference to problems in astronomy.

¹ Similar rules occur in BrSpSi, xxx. 35 and ŚīDVṛ, I, i. 51 (i).
Preliminary operation to be performed on the divisor and dividend of a pulveriser:

41. The divisor (which is "the number of civil days in a yuga") and the dividend (which is "the revolution-number of the desired planet") become prime to each other on being divided by the (last non-zero) residue of the mutual division of the number of civil days in a yuga and the revolution-number of the desired planet. The operations of the pulveriser should be performed on them (i.e., on the abraded divisor and abraded dividend). So has been said.

An indeterminate equation of the first degree of the type
\[ \frac{ax - c}{b} = y \]
(with \(x\) and \(y\) unknown) is known in Hindu mathematics by the name of "pulveriser (kuṭṭākāra)"). In this equation, \(a\) is called the "dividend", \(b\) the "divisor", \(c\) the "interpolator", \(x\) the "multiplier", and \(y\) the "quotient".

In the pulveriser contemplated in the above stanza,

\(a = \) revolution-number of a planet,

\(b = \) civil days in a yuga,

\(c = \) residue of the revolutions of the planet,

\(x = ahargana,\)

and \(y = \) complete revolutions performed by the planet.

The text says that as a preliminary operation to the solution of this pulveriser, \(a\) and \(b\), i.e., civil days in a yuga and revolution-number of the planet, should be made prime to each other by dividing them out by their greatest common factor. That is to say, in solving a pulveriser one should always make use of abraded divisor and abraded dividend.

The interpolator, i.e., the residue, should also be divided out by the same factor. This instruction is not given in the text, but it is implied that the residue should be computed for the abraded dividend and abraded divisor.
A rule for solving a pulveriser, when the dividend is smaller than the divisor:

42-44. Set down the dividend above and the divisor below that. Divide them mutually, and write down the quotients of division one below the other (in the form of a chain). (When an even number of quotients are obtained) think out by what number the (last) remainder be multiplied so that the product being diminished by the (given) residue be exactly divisible (by the divisor corresponding to that remainder). Put down the chosen number (called \textit{mati}) below the chain and then the new quotient underneath it. Then by the chosen number multiply the number which stands just above it, and to the product add the quotient (written below the chosen number). (Replace the upper number by the resulting sum and cancel the number below). Proceed afterwards also in the same way (until only two numbers remain). Divide the upper number (called "the multiplier") by the divisor by the usual process and the lower one (called "the quotient") by the dividend: the remainders (thus obtained) will respectively be the \textit{aharga\={n}a} and the revolutions, etc., or what one wants to know.

We explain this rule by means of an example.\footnote{1}

Example. The residue of the revolutions of Saturn is 24, find the \textit{aharga\={n}a} and the revolutions performed by Saturn.\footnote{2}

The revolution-number of Saturn is 146564, and the number of civil days in a \textit{yuga} is 1577917500. In the present problem these are respectively the dividend and the divisor. Their H.C.F. is 4, so that dividing them out by 4 we get 36641 and 394479375 as the abraded dividend and the abraded divisor respectively. We have, therefore, to solve the pulveriser

\[
\frac{36641x-24}{394479375} = y,
\]

where \(x\) denotes the \textit{aharga\={n}a} and \(y\) the revolutions made by Saturn.\footnote{3}

\footnote{1}{For other details, the reader is referred to B. Datta and A. N. Singh, \textit{History of Hindu Mathematics}, Part II, P. 87 ff.}

\footnote{2}{Based on Bhāskara I's problem given in \textit{LBh}, viii. 17.}

\footnote{3}{We have not divided the given residue 24 by 4, because it is already computed for the abraded dividend and abraded divisor.}
Mutually dividing 36641 and 394479375, we have

\[
\begin{array}{c}
36641) 394479375 (10766 \\
394477006 \\
2369) 36641 (15 \\
35535 \\
1106) 2369 (2 \\
2212 \\
157) 1106 (7 \\
1099 \\
7) 157 (22 \\
154 \\
3) 7 (2 \\
6 \\
1 \times 27 - 24 = 3(1 \\
3 \\
0
\end{array}
\]

We have chosen here the number 27 as the optional number \((mati)\).\(^1\)

Writing down the quotients one below the other as prescribed in the rule, we get the chain

\[
\begin{array}{c}
10766 \\
15 \\
2 \\
7 \\
22 \\
2 \\
(mati) 27 \\
1
\end{array}
\]

\(^1\) The \(mati\) may be chosen at any stage after an even number of quotients are obtained.
Reducing the chain, we successively get

\[
\begin{array}{cccccccc}
10766 & 10766 & 10766 & 10766 & 10766 & 3108044439 & \text{(multiplier)} \\
15 & 15 & 15 & 15 & 288689 & 288689 & \text{(quotient)} \\
2 & 2 & 2 & 18665 & 18665 & \\
7 & 7 & 8714 & 8714 & \\
22 & 1237 & 1237 & \\
55 & 55 & \\
27 & \\
\end{array}
\]

Dividing 3108044439 by 394479375, and 288689 by 36641, we obtain 346688814 and 32202 respectively as remainders.\(^1\) These are the minimum values of \(x\) and \(y\) satisfying the above equation.

Therefore, the required \(ahargaṇa = 346688814\), and the revolutions performed by Saturn = 32202.

*General solution.* The general solution of the above equation (*vide* stanza 50) is

\[
x = 394479375\alpha + 346688814, \\
y = 36641\alpha + 32202,
\]

where \(\alpha = 0, 1, 2, 3, \ldots\ldots\)

An alternative rule:

- 45-46(i). Alternatively, the pulveriser is solved by subtracting one (i.e., by assuming the residue to be unity). The upper and lower quantities (in the reduced chain) are the (corresponding) multiplier and quotient (respectively). By the multiplier and quotient (thus obtained) multiply the given residue, and then divide the respective products by the abraded divisor and dividend. The remainders obtained are here (in astronomy) the \(ahargaṇa\) and the revolutions (performed respectively).

\(^1\) This division is performed only when the multiplier and quotient are greater than the divisor and dividend respectively.
The pulveriser

\[ \frac{ax - c}{b} = y \]  \hspace{1cm} (1)

may be written as

\[ \frac{aX - 1}{b} = Y, \]  \hspace{1cm} (2)

where \( x = cX \), and \( y = cY \). If \( X = \alpha \), \( Y = \beta \) is a solution of (2), then \( x = c\alpha \), \( y = c\beta \) will be a solution of (1). Hence the above rule.\(^1\)

A rule for finding the residue of revolutions from the longitude of a planet given in signs, etc.:

46(ii). (In case the longitude of a planet is given in terms of signs, etc.,) the signs, etc., are multiplied by the abraded number of civil days (in a \textit{yuga}) and the product is divided by the number of signs, etc., (in a circle). The quotient is stated to be the residue (of revolutions).

When the longitude is given in terms of signs, it should be multiplied by the abraded number of civil days in a \textit{yuga} and then the product should be divided by 12. The quotient thus obtained should be used as the residue of revolutions. When the longitude is given in terms of signs and degrees, it should be reduced to degrees, then the resulting degrees should be multiplied by the abraded number of civil days in a \textit{yuga} and the product should be divided by 360. The quotient should be treated as the residue of revolutions. When the longitude is given in terms of signs, degrees, and minutes, it should be reduced to minutes, then the resulting minutes should be multiplied by the abraded number of civil days in a \textit{yuga} and the product should be divided by 21600. The quotient should be used as the residue of revolutions.

Let \( x \) be the \textit{ahargaña}, \( y \) the revolutions performed by a planet, and \( s \) signs the given residue. Then

\[ \frac{(\text{abraded revolution-number}) \times x}{\text{abraded civil days}} - s \text{ signs} = y, \]

or

\[ \frac{(\text{abraded rev.-number}) \times x - \frac{\text{abraded civil days}}{12} \times s}{\text{abraded civil days}} = y. \]

\(^1\) For illustration see Example under stanza 46 (ii).
Hence the above rule.

Example. "The mean (position) of the Sun has been observed by me at sunrise to be in the sign Leo in the middle of the navamāṃśa Sagittarius. Calculate the ahargāṇa according to the (Arya)bhaṭa-śāstra, and also the revolutions performed by the Sun since the beginning of Kaliyuga."\(^1\)

The mean longitude of the Sun = 4 signs 28° 20’

\[= 8900’.\]

The abraded revolution-number of the Sun = 576,
and the abraded number of civil days in a yuga = 210389.
Hence, by the above rule, the residue of revolutions = 86688.
We have, therefore, to solve the equation

\[
\frac{576 \times 86688}{210389} = y,
\]

where \(x\) is the ahargāṇa and \(y\) the number of revolutions performed by the Sun.

Solving this equation with unit residue, we get
\[x = 94602,\]
\[y = 259.\]

Deducing the solution for the given residue\(^2\), we get
\[x = 105345,\]
\[y = 288,\]

which is the minimum solution of the problem. The general solution is
\[x = 210389\alpha + 105345,\]
\[y = 576\alpha + 288,\]

where \(\alpha = 0, 1, 2, 3, \ldots\)

A rule for solving a pulveriser when the dividend is greater than the divisor:

47. When the dividend is greater than the divisor, then, having subtracted the greatest multiple of the divisor (from

\(^1\) Bhāskara I's example occurring in his comm. on \(\overline{A}\), ii. 32-33.
\(^2\) See the rule given in stanzas 45-46(i).
the dividend), apply the same process (as prescribed in stanzas 42-44 or 45-46 (i)). Multiply the multiplier (thus obtained) by that multiple and (to the product) add the quotient: the result will be the quotient here (required).

Let the pulveriser be

$$\frac{ax - c}{b} = y,$$  \hspace{1cm} (1)

where $a > b$. Then if, $a = mb + A, A < b$, (1) may be written as

$$\frac{Ax - c}{b} = Y,$$  \hspace{1cm} (2)

where $y = Y + mx$.

If $x = \alpha, Y = \beta$, be a solution of (2), then $x = \alpha, y = m\alpha + \beta$ will be a solution of (1). Hence the above rule.

Example. "The signs, etc., up to the thirds of the Sun's (mean) longitude have all been carried away by the strong wind; the residue of thirds is known to me to be 101. Tell (me) the Sun's (mean) longitude and also the ahargaṇa."

The abraded dividend for the Sun = 576 revolutions

$$= 576 \times 12 \times 30 \times 60 \times 60 \times 60 \text{ thirds}$$

$$= 44789760000 \text{ thirds}.$$

We have, therefore, to solve the equation

$$\frac{44789760000 \times x - 101}{210389} = y,$$  \hspace{1cm} (3)

where $x$ is the ahargaṇa and $y$ the thirds described by the Sun since the beginning of Kaliyuga.

Since in this equation the dividend 44789760000 is greater than the divisor 210389, therefore, as directed in the above rule, we divide out the dividend by the divisor, and put the equation in the form

$$\frac{45790 \times x - 101}{210389} = Y,$$  \hspace{1cm} (4)

1 The literal translation is "the lower quantity (in the reduced chain)", which means "the quotient".

2 MBh, viii. 13.
where \( Y \) is related to \( y \) by the relation \( y = 212890 \, x + Y \).^1

Solving this equation, we get

\[
\begin{align*}
x &= 106141, \\
Y &= 23101.
\end{align*}
\]

Hence the solution of the equation (3) is

\[
\begin{align*}
x &= 106141, \\
y &= 212890 \, x + Y \\
&= 22596380591.
\end{align*}
\]

The required \textit{ahargana} is therefore 106141; and the mean longitude of the Sun is 22596380591 thirds, i.e., 3 signs, 32 degrees, 52 minutes, 23 seconds, and 11 thirds.

\textit{Alternative method.} When \( a > b \), the pulveriser

\[
\frac{ax - c}{b} = y
\]

may be written as

\[
\frac{by + c}{a} = x,
\]

which can be solved ordinarily by applying the rule stated in stanza 51 below.

A rule for solving the so called \textit{vāra-kūtākāra} (week-day pulveriser):

48. Divide the abraded number of civil days (in a \textit{yuga}) by 7. Take the remainder as the dividend, and 7 as the divisor. Also take the excess 1, 2, etc., of the required day over the given day as the residue. Whatever number (i.e., multiplier) results on solving this pulveriser is the multiplier of the abraded number of civil days. The product of these added to the

---

^1 212890 and 45790 are obtained as the quotient and the remainder when 44789760000 is divided by 210389.
ahargana calculated (for the given day) gives the ahargana for the required day.

This rule will become clear by the following solved example.

Example. "The mean longitude of the Sun (for sunrise) on a Wednesday is stated to be 8 signs, 25 degrees, 36 minutes, and 10 seconds. Say correctly after how much time (since the beginning of Kaliyuga) will the Sun again assume the same position (at sunrise) on a Thursday, Friday, and Wednesday."

We first determine the ahargana elapsed at sunrise on Wednesday when the Sun's mean longitude is 8 signs, 25 degrees, 36 minutes, and 10 seconds.

Since the Sun's mean longitude = 8 signs 25° 36' 10"

= 956170 

therefore, by stanza 46(ii), the residue of revolutions = 155222.

Thus we have to solve the pulveriser

\[
\frac{576x - 155222}{210389} = y,
\]

where \(x\) is the ahargana and \(y\) the revolutions performed by the Sun.

Solving this equation, we obtain

\[
x = 1000,
\]

\[
y = 2.
\]

Hence the ahargana for the given Wednesday = 1000.

(i) Now we find out the ahargana elapsed at sunrise on a Thursday when the Sun again occupies the same position.

Let the required ahargana be 1000 + \(A\). Then in \(A\) days the Sun will describe complete revolutions. Also since Thursday is in advance of

---

1 The text is a little obscure at this place. Our translation is based on the interpretations given by the commentators. It also agrees with the details of the rule supplied by the author Bhāskara I himself in his commentary on \( \overline{A} \), ii. 32-33.

2 Bhāskara I's example occurring in his comm. on \( \overline{A} \), ii. 32-33.
Wednesday by one day, the residue of the week-cycle is unity. In other words,

\[ \frac{576A}{210389} \quad \text{and} \quad \frac{A-1}{7} \]

will be whole numbers. If we assume \( A \) to be a multiple of 210389, we have simply to determine \( A \) such that \( A-1 \) may be completely divisible by 7.

Let \( A = 210389X \). Then we have to solve the pulveriser

\[ \frac{210389X - 1}{7} = Y, \] (1)

or (vide stanza 47)

\[ \frac{4X - 1}{7} = Y', \] (2)

where \( Y = 30055X + Y' \). This is what the rule prescribes.

Evidently, a solution of (2) is \( X = 2, Y' = 1 \). The corresponding solution of (1) is \( X = 2, Y = 30055 \times 2 + 1 = 60111 \).

The required ahargaṇa is therefore 1000 + \( A \), i.e., 1000 + 210389X i.e., 1000 + 210389 \times 2 or 421778.

(ii) To find the ahargaṇa for Friday.

In this case, the residue of the week-cycle is 2. Let the required ahargaṇa be 1000 + 210389X. Then we have to solve the pulveriser

\[ \frac{210389X - 2}{7} = Y, \] (3)

or (vide stanza 47)

\[ \frac{4X - 2}{7} = Y', \] (4)

where \( Y = 30055X + Y' \).

Evidently, a solution of (4) is \( X = 4, Y' = 2 \). The corresponding solution of (3) is \( X = 4, Y = 30055X + 2 = 120222 \).

The required ahargaṇa is therefore 842556.

(iii) To find the ahargaṇa for Wednesday.

As before, let the ahargaṇa be 1000 + 210389X. In this case, the residue of the week-cycle is 0 and we evidently have \( X = 7 \), so that the required ahargaṇa is 1473723.

A rule for the solution of the so called velā-kuttākāra (time-pulveriser):

49. First make the abraded dividend and the (new)
divisor prime to each other. Then by what remains as the (new) divisor multiply the abraded divisor (and also the residue). Thereafter the process for the time-pulveriser is the same as described before (for the ordinary pulveriser).

This rule is applicable when the ahargaṇa is not a whole number but a whole number and a fraction\(^1\). That is to say, when the pulveriser is of the type

\[
\frac{a(x \pm r/s) - c}{b} = y. \tag{1}
\]

Let \(a = mA\), and \(s = mB\), \(m\) being the greatest common factor of \(a\) and \(s\). Then the equation (1) can be written as

\[
\frac{AX - Bc}{Bb} = y, \tag{2}
\]

where \(X = sx \pm r\).

The above rule tells us that whenever we have to solve an equation of the form (1), we must solve it by reducing it to the form (2). If \(X = \alpha\), \(y = \beta\) is a solution of equation (2), then \(x = (\alpha \mp r)/s\), \(y = \beta\) will be a solution of equation (1).

Example 1. “The (mean) longitude of the Sun for midnight is found to be 9 signs, 15 degrees, 32 minutes, and 40 seconds. Quickly say the ahargaṇa and the revolutions (performed by the Sun) according to the Āśmakīya.”\(^2\)

Since the mean longitude of the Sun = 9 signs 15\(^o\) 32' 40", therefore, by stanza 46 (ii), the residue of revolutions = 166876.

We have, therefore, to solve the equation

\[
\frac{576 (x - 1/4) - 166876}{210389} = y. \tag{3}
\]

where \(x - 1\) is the required ahargaṇa and \(y\) the revolutions performed by the Sun.

As this equation is of the form (1), we reduce it to the form (2) as prescribed in the rule. Thus we get

\[
\frac{144X - 166876}{210389} = y, \tag{4}
\]

where \(X = 4x - 1\).

\(^1\) The “(new) divisor” of the text is the denominator of this fraction.

\(^2\) Bhāskara I’s example, occurring in his comm. on Ā, ii. 32-33,
Solving equation (4), we get $X = 7003$, $y = 4$, giving $x = 1751$.

Hence the required \textit{aharga\=na} is 1750, and the number of revolutions performed by the Sun is 4.

Example 2. "The revolutions, etc., of the Sun's mean longitude, calculated from an \textit{aharga\=na} plus a few \textit{n\=ad\=is} elapsed, have now been destroyed by the wind; 71 minutes are seen by me to remain intact. Say the \textit{aharga\=na}, the Sun's (mean) longitude, and the correct value of the \textit{n\=ad\=is} (used in the calculation)." 1

Here we have to solve the equation

$$\frac{576 \times 12 \times 30 \times 60 (x + n/60) - 71}{210389} = y,$$

(5)

where $x$ is the \textit{aharga\=na}, $y$ the minutes traversed by the Sun since the beginning of the Kaliyuga, and $n$ the \textit{n\=ad\=is} elapsed.

As this equation is of the form (1), we reduce it to the form (2), and thus we get

$$\frac{207360X - 71}{210389} = y,$$

(6)

where $X = 60x + n$.

Solving equation (6), we obtain

\begin{align*}
X &= 43203, \\
y &= 42581,
\end{align*}

whence we have $x = 720$, and $n = 3$.

Hence the \textit{aharga\=na} is 720, the \textit{n\=ad\=is} elapsed are 3, and the mean longitude of the Sun is 42581 minutes, i.e., 11 signs, 19 degrees, and 41 minutes.

A rule for getting the other solutions of a pulveriser with the help of the known minimum solution:

50. (To obtain the other solutions of the pulveriser) the intelligent (astronomer) should again and again add the divisor to the multiplier and the dividend to the quotient as in the process of \textit{prast\=ara} ("representation of combinations").

---

1 Bh\=askara I's example, occurring in his comm. on \=A, iii. 32-33, and in \=MBh, viii. 23.
That is to say, if \( x = \alpha, y = \beta \) is the minimum solution of the pulverser

\[
\frac{ax - c}{b} = y,
\]

then the other solutions of the same pulverser are

\[
x = mb + \alpha, \\
y = ma + \beta,
\]

where \( m = 1, 2, 3, \ldots \).

Procedure for problems in which the given quantity is the part of the revolution to be traversed by a planet:

51. When the part (of the revolution) to be traversed by some (planet) is the given quantity, then (also) the same process should be applied, treating the part to be traversed as the additive, or taking unity as the additive. All details of procedure are the same (as before).

The pulverser contemplated above is of the type

\[
\frac{ax + c}{b} = y. \tag{1}
\]

According to the above rule, this is to be solved in the same way as

\[
\frac{ax - c}{b} = y, \tag{2}
\]

with the difference that wherever in solving (2) \( c \) is subtracted, in solving (1) it should be added. Or, the solution of (1) may be derived as before from the solution of

\[
\frac{ax + 1}{b} = y. \tag{3}
\]

Example. "Given that 100 minutes of the eighth sign are to be traversed by the Sun, say quickly, after carefully considering, O intelligent one, if the Ga\textit{qita} of Âšmaka is known to you, all the years that have elapsed this day since the beginning of Kaliyuga. Also say the number of days that have elapsed since the beginning of Kaliyuga."\(^2\)

\(^1\) It is also possible to reduce the pulverser (1) to the form (2). For, when the part of the revolution to be traversed by a planet is given, the part traversed may be easily derived therefrom.

\(^2\) Bhāskara I's example, occurring in his comm. on \( A \), ii, 32-33.
Here, according to Bhāskara I's interpretation, the part of the revolution to be traversed by the Sun = 7 signs 100'. The corresponding residue of revolutions = 123707. This is positive.

We have, therefore, to solve the equation

\[
\frac{576x + 123701}{210389} = y,
\]

where \(x\) is the required \(\text{ahargaṇa}\), and \(y - 1\) the number of years elapsed.

Mutually dividing 576 and 210389 and taking 1 for the optional number (\(\text{mati}\)) after six quotients, we get the following chain

\[
\begin{align*}
365 \\
3 \\
1 \\
6 \\
2 \\
4 \\
1 \ (\text{mati}) \\
61851
\end{align*}
\]

which reduces to

\[
\begin{align*}
1310408037 \\
3587617
\end{align*}
\]

Dividing 1310408037 by 210389 and 3587617 by 576, we obtain as remainders 105345 and 289 respectively. Therefore \(x = 105345\), \(y = 289\).

Hence the required \(\text{ahargaṇa} = 105345\), and the number of years elapsed = 288.

Note. According to Govinda Svāmi's interpretation the part of the revolution to be traversed by the Sun = 4 signs 10' 40'. The corresponding residue of the revolution = 71104.

The resulting pulveriser is

\[
\frac{576x + 71104}{210389} = y,
\]

of which the solution is \(x = 186889\), \(y = 512\).

Therefore, the required \(\text{ahargaṇa} = 186889\), and the number of years elapsed = 511.
Rules relating to the two cases: (i) when the sum or difference of the residues (of revolutions) of any two planets is given, and (ii) when the residues for two or more planets are given separately:

52. When the sum of the residues (of revolutions of two or more planets) is given, proceed with the sum of their revolution-numbers (as the dividend); and when the difference between the residues (for any two planets) is given, proceed with the difference of their revolution-numbers (as the dividend). When the residues (for two or more planets) are given (separately), think out the method of solution by the help of the given residues and the true revolution-numbers of the given planets.

These rules will be clear from the following solved examples.

Example 1. "The sum of the (mean) longitudes of Mars and the Moon is calculated to be 5 signs, 7 degrees, 9 minutes, (9 seconds, and 6 thirds). O you, well versed in the (Ārya)bhaṭa-tantra, quickly say the ahargaṇa and also the (mean) longitudes of the Moon and Mars."¹

The revolution-number of the Moon = 57753336.
The revolution-number of Mars = 2296824.
Their sum = 60050160.
The number of civil days in a yuga = 1577917500.

The H. C. F. of 60050160 and 1577917500 is 60. Therefore, the abraded sum of the revolution-numbers of the Moon and Mars

= 60050160 ÷ 60 = 1000836,

and the abraded number of civil days = 1577917500 ÷ 60 = 26298625.

The sum of the mean longitudes of the Moon and Mars

= 5 signs 7⁰ 9′ 9″ 6‴

= 33944946 thirds.

Therefore, by stanza 46(ii), the residue of revolutions = 11480265.
We have, therefore, to solve the equation

\[
\frac{1000836 \times 11480265}{26298625} = y,
\]

¹ Bhāskara I's example (MBh, viii. 19) with Govinda Svāmī's modification.
where \( x \) denotes the required ahargaṇa.

The minimum solution of this equation is
\[
x = 10157490, \\
y = 386459.
\]

The required ahargaṇa is, therefore, 10157490. The mean longitudes of the Moon and Mars can be easily calculated from this ahargaṇa.

Example 2. "The difference between the mean longitudes of Mars and Jupiter is exactly 5 signs. Say what is the number of days elapsed since the beginning of Kaliyuga and what are the (mean) longitudes of Jupiter and Mars." ¹

The revolution-number of Mars = 2296824.  
The revolution-number of Jupiter = 364224.  
Their difference = 1932600.  
Also the number of civil days = 1577917500.

The H. C. F. of 1932600 and 1577917500 is 300. Therefore, the abraded difference of the revolution-numbers of Mars and Jupiter = 1932600 \( \div \) 300, i.e., 6442, and the abraded number of civil days = 1577917500 \( \div \) 300, i.e., 5259725.

The difference between the mean longitudes of Mars and Jupiter = 5 signs. Therefore, by stanza 46(ii), the residue of revolutions = 2191552.

Hence we have to solve the equation
\[
\frac{6442 \times -2191552}{5259725} = y,
\]
where \( x \) denotes the required ahargaṇa.

The minimum solution of this equation is
\[
x = 1133606, \\
y = 1388.
\]

The required ahargaṇa is therefore 1133606. The corresponding mean longitudes of Mars and Jupiter may be easily obtained.

¹ Mbh, viii. 20.
Example 3. "Some number of days is (severally) divided by the (abraded) civil days for the Sun and for Mars. The (resulting) quotients are unknown to me; the residues, too, are not seen by me. The quotients obtained by multiplying those residues by the respective (abraded) revolution-numbers and then dividing (the products) by the respective (abraded) civil days are also blown away by the wind. The remainders of the two (divisions) now exist. The remainder for the Sun is 38472, and that for Mars is 77180625. From these remainders severally calculate, O mathematician, the ahargaṇas for the Sun and Mars and also the ahargaṇa conforming to the two residues and state them in proper order."¹

The abraded revolution-number and the abraded civil days for the Sun are 576 and 210389 respectively; the same for Mars are 191402 and 131493125 respectively.

Let \( A \) be the number of days (i.e., the ahargaṇa conforming to the two residues). Then suppose that

\[
\begin{align*}
\frac{A}{210389} &= x + \frac{a}{210389} \\
\frac{A}{131493125} &= y + \frac{b}{131493125}
\end{align*}
\]

and

\[
\begin{align*}
\frac{576}{210389} &= \beta + \frac{38472}{210389} \\
\frac{191402}{131493125} &= \lambda + \frac{77180625}{131493125}
\end{align*}
\]

where \( A \), \( x \), \( y \), \( a \), \( b \), \( \beta \), and \( \lambda \) are all unknown quantities. The problem is to find \( a \) and \( b \) and therefrom \( A \).

The equations (2) reduce to

\[
\begin{align*}
\frac{576a - 38472}{210389} &= \beta, \\
\frac{191402b - 77180625}{131493125} &= \lambda
\end{align*}
\]

¹ Bhāskara I's example, occurring in his comm. on Ā, ii. 32-33. Also see MBh, viii. 24-24*.
Solving \((3)\), we get \(a = 8833\), \(\beta = 24\); and solving \((4)\), we get \(b = 640000\), \(\lambda = 931\).

Hence the *ahargana* for the Sun is 8833, and that for Mars 931.

The equations \((1)\) now reduce to

\[
A = 210389 \times 8833 = 131493125 \times y + 640000,
\]

whence we get the pulveriser

\[
\frac{210389 \times 631167}{131493125} = y, \\
\]

i.e.,

\[
\frac{x - 3}{625} = y, \quad (5)
\]

The minimum solution of \((5)\) is evidently

\[
x = 628, \\
y = 1.
\]

Hence \(A = 132133125\).

The *ahargana* conforming to the two residues \(a = 8833\) and \(b = 640000\) is therefore equal to 132133125.
CHAPTER II

THE LONGITUDE-CORRECTION

Names of certain places lying on the Hindu prime meridian:

1-2. From Laṅka (towards the north, we have the following places on the prime meridian): Kharanagara, Sitorugeha, Paṇāṭa, Misitapurī, Taparnī, the lofty mountain called Sitavara, the wealthy town called Vātsyagulma, the well-known Varanagari, Avanti. Sthānēsa, and then Meru, which is inhabited by happy people. For those who reside in these places, the correction for the longitude (of the local place) does not exist.

Laṅkā in Hindu astronomy denotes the place where the Hindu prime meridian passing through Ujjain1 intersects the equator (i.e., the place in 0 latitude and 0 longitude). It is one of the four hypothetical cities on the equator, called Laṅkā, Romaka, Siddhapura, and Yamakoṭi. Laṅkā is described in the Sūrya-siddhānta2 as a great city (mahāpurī) situated on an island (dvīpa) to the south of Bhārata-varṣa (India). The island of Ceylon which bears then ame Laṅkā, however, is not the astronomical Laṅkā, as the former is about six degrees to the north of the equator.

Kharanagara ("the town of Khara") is probably the place near Nasik where Khara, cousin of Rāvaṇa, lived. SitorUGEha has not been identified.

Paṇāṭa seems to have been an important place, as it has been mentioned by other astronomers also, such as Lalla, Vateśvara, and Śripati. Lalla has called it by the name Pānāṭa, and Śripati by the name Pānāṭa. We have not been able to identify this place also.

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1 Situated in latitude 23° 11′ N. and longitude 75° 52′ east of Greenwich.
2 xii. 37, 39,
LONGITUDE-CORRECTION

Misitapuri and Taparni, too, remain unidentified. Šaṅkaraṅārāyaṇa in his commentary on the Lāghu-Bhāskarīya⁰ pronounces Misitapura as Nisitapura, so it is difficult to say which pronunciation is correct.

The Sitavara mountain ("the excellent white mountain") is the Śvetaśaila of Lalla, the Sītādri of Śrīpati, and the Sitaparvata of Bhāskara II. According to Śrīpati, it is the seat of the six-faced god Śvāmikārtikeya. It can therefore be identified with Krauṅcagiri or Kumāra-parvata, situated at a distance of 3 yojanas from Śrīśaila.²

Vātsyagulma is the town of Vatsarāja Udayana, usually called Vatsapattana. It has been identified with Kauśāmbī (modern Kosam) situated on the river Jumna at a distance of about 38 miles from Allahabad.

Vananagari³ is probably Tumba-vana-nagara (modern Tumain) in Madhya Bhārata. Avanti is modern Ujjain. Sthāneśa is Sthāneśvara, a place in Kurukṣetra. Meru is the north pole.

From the above identification we find that the places mentioned in the text do not lie precisely on one meridian. The places mentioned by other astronomers also do not satisfy this requirement. It has not been possible to give any satisfactory explanation to this discrepancy. Probably the geographical knowledge of ancient Hindu writers was not sound in respect of places other than their own.

We give below the lists of places lying on the Hindu prime meridian according to other Hindu astronomers which will be useful for comparison and reference.

(i) Lalla’s list.⁴ Laṅkā, Kumārī, Kāñci(varam), Pārṇāṭā, Kṛṣṇā (the river), Śvetaśaila ("the white mountain"), Vātsyagulma, Ujjayini, Gargarat, Āśraya (? Āśrama), Mālavanagara, Cāyuṣiva (?), Rohitaka (Rohtak), Kurukṣetra (the battle field of the Bhārata War), Himavān (the Himalayas), and Meru.

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¹ i. 23.
² See Kalyāṇa, Tīrthāṅka, pp. 310 and 330.
³ In case the correct reading is Varanagari, it may be identified with Barnagar.
⁴ Mentioned in Āmarāja’s comm. on KK, i. 13.
(ii) Vaṭeśvara's list. Laṅkā, Kumāri, Kāñci, Māṇīṭamaśvetapuri, Śveta Acala, Vatsayagulma, Avanti-pūr, Gargarāṭ, Āśrama-pattana, Mālavangara, Patṭaśīva, Rohitaka, Sthāṇviśvara (Sthāneśvara), Himavān, and Meru.

(iii) Śrīpati's list. Laṅkā, Kumāri, Kāñci-nagari, Pānāṭa, Saḍāsyā Sitādri, Śrī Vatsagulma, Māhīṣmati (modern Mahāśvara situated on the north bank of river Narmada in Nimar district in Madhya Bhārata), Ujjayinī, Āśrama-nagara, Paṭṭaśīva, Śrī Gargarāṭ, Rohita (Rohtak), Sthāṇviśvara, Śītaśīra (the Himalayas), and Sumeru.

(iv) Bhāskara II's lists.

1. Laṅkā-pūrī, Vatsagulma, Māhīṣmati, Ujjayinī, Gargarāṭ, Kurukṣetra, Himācala, etc.

2. Laṅkā, Devakanyā, Kāñci, Sītaśīra, Paryā, Vatsagulma, Ujjayinī-pūrī, Gargarāṭ, Kurukṣetra, and Meru.

(v) List of the Sūrya-siddhānta. Rākṣasālaya (i.e., Laṅkā), Devauka Śaila (i.e., Meru), Rohitaka (modern Rohtak), Avanti, and Sannihita Sara.

A rule for finding the distance of a place from the prime meridian:

3-4. Subtract the degrees of the latitude of one of the places (lit. towns) mentioned above from the degrees of the (local) latitude; then multiply (the degrees of the difference) by 3299 minus 8/25, and divide (the product) by the number of degrees in a circle (i.e., by 360). The resulting yojanas constitute the upright (koti). The oblique distance between the local

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1 VSf, chapter I, section ix, stanzas 1-2.
2 A compound word giving the names of two places which probably correspond to Pānāṭa and Misitapuri mentioned in the text.
3 SiŚe, ii. 95-97.
4 Comm. on ŚiDVṛ, i. 55.
5 KKu, i. 14.
6 SiŚi, i. 62.
7 Sannihita Sara is in Kurukṣetra. See Kālyāga, Tīrthāṅka, p. 79.
place and the place (on the prime meridian) chosen above, which is known in the world by the utterance of the common people, is the hypotenuse. The square root of the difference between their squares (i.e., between the squares of the hypotenuse and the upright) is defined by some astronomers to be the distance (in yojanas of the local place from the prime meridian).\(^1\)

In Fig. 2, let CD be a portion of the prime meridian and AB that of the local circle of latitude. Let L be the local place and X a place on the prime meridian. L and X being joined, we get the right-angled triangle XYL. The above rule tells us how to determine the distance YL of L from the prime meridian in linear units (i.e., in yojanas). The triangle XYL is supposed to be plane and sides XY, YL, and XL are taken as the upright (koti), the base (bhuj), and the hypotenuse (karga) respectively.

Subtracting the degrees of the latitude of X from those of L (or Y), we get the length XY in terms of degrees. Now the circumference of the Earth is equal to 3299 minus 8/25 yojanas in linear units and to 360 degrees in circular units; therefore, multiplying the degrees of XY by 3299 minus 8/25 and dividing the product by 360, we get the upright (koti) XY in terms of yojanas. The hypotenuse XL is assumed to be known in terms of yojanas by common usage. Hence the above rule.

**Earth's circumference.** In the above rule, as according to Bhāskara I also, the diameter of the Earth has been taken to be equal to 1050 yojanas\(^2\) and \(\pi\) equal to 3·1416. Therefore,

\[
\text{the circumference of the Earth} = 1050 \times 3\cdot1416 \text{ yojanas} = 3298\cdot68 \text{ yojanas} = (3299-8/25) \text{ yojanas.}
\]

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\(^1\) This rule is found also in BrSpSi, i. 36; LBh, i. 25-26; ŚiDVṛ, I, 57-58 (i); SiSa, i. 143-144.

\(^2\) Vide infra, chapter V, stanza 4,
In the *Laghu-Bhāskarīya*, the author has neglected the fraction 8/25 and has given the whole number 3299 as the *yojanas* of the Earth’s circumference. Lalla has prescribed the more convenient number 3300.

**Criticism of the above rule:**

5. The distance (obtained above) has been stated to be incorrect by the disciples of (Ārya)bhaṭa, who are well versed in astronomy, on the ground that the method of knowing the hypotenuse is gross. (Those) wise people further say that on account of the sphericity of the earth (also), the method used for deriving the above rule commencing with “*akṣa*” is inaccurate.

Śrīpati, too, has criticised the above rule for the same reasons. His commentator Makkibhaṭṭa sums up his criticism in the following words:

“The above rule is incorrect, because of the curvature of the Earth and because of uncertainty of the distances in *yojanas* depending on hearsay. No intelligent person has verified the popular (estimates of distances in) *yojanas* by actual measurement with the help of hand, staff, or rope. Therefore, in the face of plurality of popular estimates of distances, this rule is improper.”

It is noteworthy that the inaccurate rule criticised above occurs in the *Brāhma-sphuṭa-siddhānta* of Brahmagupta and in the *Śiṣṭya-dhī-vṛddhida* of Lalla.

**Criticism of another rule:**

6. Some (astronomers) say that the minutes of the difference between the true longitude of the Sun calculated from the midday shadow (of the gnomon at the local place)

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1. *LBh*, i. 24.
2. *ŚiDVr*, i. i. 56.
3. This criticism occurs also in *LBh*, i. 27 and *ŚiŚe*, i. 104.
4. *ŚiŚe*, ii. 104(1), comm.
5. i. 36.
6. *I*, i. 57-58(i).
and the true longitude of the Sun calculated (from the ahargana) for the middle of the day (without the application of the longitude-correction) give the longitude (correction for the Sun). This also is not so, because for people who live on the same parallel of latitude, the latitude (and therefore the shadow of the gnomon) is the same.

This rule has also been criticised by Śrīpati, who says:

"Whatever is obtained here as the difference between the longitude of the Sun obtained from the midday shadow and that obtained by calculation (for midday, without the application of the longitude-correction) when multiplied by the (local) circumference of the Earth and divided by the (Sun’s daily) motion gives the yojanas of the longitude (i.e., the distance in yojanas of the local place from the prime meridian). This is gross on account of the small change in the Sun’s declination."³

A rule for finding the longitude in time:

7. Those who have studied the astronomical tantra composed by (Ārya)bhaṭa and are well versed in Spheres state that the difference between the time of an eclipse calculated by the usual method from the longitudes of the Sun and the Moon (both) uncorrected for the longitude-correction and the time of the eclipse determined by observation is the more accurate value of the (longitude in) time.⁴

“Choice is made, of course, of a lunar eclipse, and not of a solar, for the purpose of the determination of longitude, because its phenomena, being unaffected by parallax, are seen everywhere at the same instant of absolute time; and the moments of the total disappearance and first reappearance of the moon in a total eclipse are further selected, because

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¹ See also LBh, i. 28.
² The local circumference of the Earth is the circumference of the local circle of latitude.
³ Śiśe, ii. 103.
⁴ Similar rules occur also in LBh, i. 29; Śiśe, ii. 106(i); TS, i. 31(ii)-32(i).
the precise instant of their occurrence is observable with more accuracy
than that of the first and last contact of the moon with the shadow".¹
Thus, says Nilakantha, "whatever accrues as the difference between (the
local times of) immersion (of a lunar eclipse) corresponding to the local
and prime meridians is the time due to the longitude (of the local
place). This may also be obtained from (the difference between the
corresponding times for) the emersion of the lunar eclipse".²

The calculated time is the local time for the place lying at the
intersection of the prime meridian and the local circle of latitude, while
the observed time is the local time for the local place. The difference
between the two is obviously the longitude in time for the local place.

Another rule:

8. On any day calculate the longitude of the Sun and
the Moon for sunrise or sunset without applying the longitude-
correction, and therefrom find the time (since sunrise or sunset),
in ghatīs, of rising or setting of the Moon;³ and having done
this, note the corresponding time in ghatīs from the water-clock.
The difference (between the two times), say the astronomers
well versed in the tantra (composed by Āryabhaṭa), is (the time
of rising at the local place of a portion of the ecliptic equal to
the motion-difference of the Sun and Moon corresponding to)
the local longitude in time. (From this, the local longitude in
time may be easily derived).

Let $\phi^\circ$ N. be the latitude and $\lambda^\circ$ E. the longitude of the local place.
Also let $T_1$ ghatīs be the time of sunrise and $T_2$ ghatīs the time of
moonrise at the place in latitude $\phi^\circ$ N. and longitude $\lambda$. Then ($T_2-T_1$)
ghatīs is the time of moonrise (as measured from sunrise) as calculated
from the longitudes of the Sun and Moon uncorrected for the longitude-
correction. For those longitudes correspond to true sunrise at the place
in latitude $\phi^\circ$ N. and longitude $\lambda$.

¹ Burgess, E., Sūrya-siddhānta (English translation), Calcutta (1935),
p. 47.
² Cf. TS, i. 31(ii)-32(i).
³ Rules for finding the time of moonrise are given in Chapter VI.
Thus the calculated time of moonrise = \( T_2 - T_1 \) ghaṭīs. (1)

At the local place, the time of sunrise on that day will be

\[ = (T_1 - \lambda/6) \text{ ghaṭīs} ; \]

and the time of moonrise will be

\[ = (T_2 - \lambda/6) \text{ ghaṭīs} - (\text{the time of rising at the local place of a portion of the ecliptic equal to} \]

\[ \lambda \text{ (Moon's daily motion in minutes} - \text{Sun's daily motion in minutes)} \]

\[ \frac{360}{360} \text{ minutes of arc.} \]

Therefore at the time of moonrise the time indicated by the water-clock will be.

\[ (T_2' - T_1) \text{ ghaṭīs} - (\text{the time of rising at the local place of a portion of the ecliptic equal to} \]

\[ \lambda \text{ (Moon's daily motion in minutes} - \text{Sun's daily motion in minutes)} \]

\[ \frac{360}{360} \text{ minutes of arc}. \] (2)

The difference between (1) and (2) gives the time of rising at the local place of a portion of the ecliptic equal to

\[ \lambda \text{ (Moon's daily motion in minutes} - \text{Sun's daily motion in minutes)} \]

\[ \frac{360}{360} \text{ minutes of arc, which is evidently the time of rising at the local place of a portion of the ecliptic equal to the motion-difference of the Sun and Moon corresponding to the longitude of the local place. Hence the rule.} \]

To obtain the local longitude in ghaṭīs we should multiply the above difference of (1) and (2) by 60 and divide the product (thus obtained) by the time in which an arc of the ecliptic equal to the difference between the daily motions of the Sun and Moon rises above the local horizon.\(^1\)

Criteria for knowing whether the local place is to the east or to the west of the prime meridian:

9. When the rising of a planet is observed before the computed time or the first contact of an eclipse is observed after the

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\(^1\) See Govinda Svāmi's commentary and the \textit{Siddhānta-dīpikā}. 
computed time, the observer is to the east of the prime meridian. In the contrary case, he is to the west (of the prime meridian).

The longitude correction and its application:

10(i). Multiply the (mean) daily motion of a planet the Sun, or the Moon's ascending node by the longitude in ghatīs and divide by 60. Apply the resulting correction to the (corresponding) mean longitude of the planet, the Sun, or the Moon's ascending node (calculated for mean sunrise at Lāṅkā) positively or negatively according as the local place is to the west or east of the prime meridian. (Thus is obtained the mean longitude of the planet, the Sun, or the Moon's ascending node for mean sunrise at the svanirakṣa place).

Rule for finding the length of the local circle of latitude and the distance of the local place from the prime meridian:

10(ii). Multiply the number of (yojanas in) the Earth's circumference by the sine of the colatitude and divide by the radius; (the result is the number of yojanas in the local circle of latitude). Multiply that by the longitude in ghatīs and divide by 60; the result (thus obtained) is stated to be the (distance in) yojanas (of the local place from the prime meridian).

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1 The computed time corresponds to the place lying at the intersection of the local circle of latitude and the prime meridian.

2 Cf. LBh, i. 29; ŚūSi, i. 63; SiŚe, ii. 105(i)-106(i).

3 The svanirakṣa place is the place where the local meridian intersects the equator.

4 This rule occurs also in LBh, i. 31 and SiŚe, ii. 106(ii).

5 Cf. ŚūSi, i. 60(i), 64(ii)-65.
CHAPTER III

DIRECTION, PLACE AND TIME. JUNCTION-STARS OF THE ZODIACAL ASTERISMS AND CONJUNCTION OF PLANETS WITH THEM

(1) DIRECTION, PLACE AND TIME.

Setting up of the gnomon:

1. After having tested the level of the ground by means of water, draw a neat circle with a pair of compasses. (At the centre of that circle, set up a vertical gnomon). The gnomon should be large, cylindrical, massive, and tested for its perpendicularity by means of four threads with plumbs tied to them.

Bhāskara I in his commentary on the Āryabhaṭīya tells us that there was difference of opinion amongst astronomers in his time regarding the shape and size of a gnomon (also called style). Some astronomers prescribed a gnomon with its one third in the bottom of the shape of a prism on a square base (caturaśra), one-third in the middle of the shape of a cow's tail (gopucchākāra), and one-third at the top of the shape of a spear-head (śulākāra); and some others prescribed a square prismatical (samacaturaśra) gnomon. The followers of Āryabhata I, he informs us, prescribed the use of a broad (prithu), massive (guru), and large (dirgha) cylindrical gnomon, made of excellent timber, and free from any hole, scar, or knot on its body. In the above stanza Bhāskara I prescribes this last kind of gnomon: the other two kinds he proves in the commentary to be defective and so he rejects them.

For getting the shadow-end easily and correctly, the cylindrical gnomon was surmounted by a fine cylindrical iron or wooden nail fixed vertically at the centre of the upper end. The nail was taken to be longer than the radius of the gnomon, so that its shadow was always seen on the ground. ²

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¹ ii. 14.
² See Bhāskara I's commentary on Ā, ii. 13. Also see Parameśvara's commentary on MBh, iii. 1.
Certain writers, Bhāskara I tells us in the commentary, prescribed a gnomon of half a cubit (\(=12\) aṅgulas) in length and having twelve divisions. But, according to Bhāskara I, (although it was the usual custom) there was no such hard and fast rule. The gnomon could be of any length and any number of divisions.\(^1\) The gnomon should, however, be large enough, so that the rings of graduation on the gnomon may be clearly seen on the shadow. A broad and massive gnomon was preferred because it was unaffected by the wind.

As regards testing the level of the ground, Bhāskara I observes:

“When there is no wind, place a jar (full) of water upon a tripod on the ground which has been made plane by means of eye or thread, and bore a (fine) hole (at the bottom of the jar) so that the water may have continuous flow. Where the water falling on the ground spreads in a circle, there the ground is in perfect level; where the water accumulates after departing from the circle of water, there it is low; and where the water does not reach, there it is high.”\(^2\) The same test has been prescribed by Govinda Svāmi\(^3\) and Nīlakanṭha.\(^4\)

After the ground was levelled, a prominently distinct circle was drawn on the ground as stated in the text. In the time of Śaṅkaraṇārāyaṇa (869 A. D.) it seems that all lines were drawn on the ground with sandal paste (candana-kṣodādra).\(^5\) The above circle having been thus drawn and coated with sandal paste, another small concentric circle was drawn with the radius of the gnomon. The gnomon was then placed vertically with the periphery of its base in coincidence with that circle. The gnomon was thus set up exactly in the middle of the bigger circle. The verticality of the gnomon was tested by means of four plumb-lines hung on the four sides of the gnomon.

A rule for finding the directions:

2. With the two points where the shadow (of the gnomon) enters into and passes out of the circle, neatly draw a fish-figure (lit. fish). The thread-line which goes through the

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\(^1\) See Bhāskara I’s comm. on \(A\), ii. 14.

\(^2\) Bhāskara I’s comm. on \(A\), ii. 13.

\(^3\) In his comm. on \(MBh\), iii. 1.

\(^4\) In his comm. on \(A\), ii. 13.

\(^5\) Vide Śaṅkaraṇārāyaṇa’s comm. on \(LBh\), iii. 1-2.
mouth and tail of the fish-figure indicates the north and south directions with respect to the gnomon.\(^1\)

Let ENWS (See Fig. 3) be the circle drawn on the ground, and O its centre where the gnomon is set. Let \(W_1\) be the point where the shadow enters into the circle (in the forenoon), and \(E_1\) the point where the shadow passes out of the circle (in the afternoon). Join \(E_1\) and \(W_1\). The line \(E_1W_1\) is directed east to west. With \(E_1\) as centre and with \(E_1W_1\) as radius\(^2\) draw an arc of a circle, and with \(W_1\) as centre and with the same radius draw another arc cutting the former at the points \(N_1\) and \(S_1\). Join \(N_1\) and \(S_1\). The line \(N_1S_1\) is directed north to south. Let the line \(N_1S_1\) meet the circle in the points \(N\) and \(S\) and the line through \(O\) drawn parallel to \(E_1W_1\) in \(E\) and \(W\). Then \(E, W, N,\) and \(S\) are respectively the east, west, north, and south directions relative to the gnomon, i.e., for an observer situated at \(O\).

The figure \(N_1E_1S_1W_1N_1\) is called “fish or fish-figure”\(^3\), and the points \(N_1\) and \(S_1\) are called the mouth and tail of the fish-figure.

As the Sun moves along the ecliptic, its declination changes. By the time the shadow moves from \(OW_1\) to \(OE_1\), the Sun traverses some distance of the ecliptic and so, theoretically speaking, its declination gets changed. It follows that \(EW\) is not the true position of the east-west line. Brahmagupta (628 A.D.) was probably the first Hindu astronomer who prescribed the determination of the east-west line with proper allowance for the change in the Sun’s declination. The details of the method intended

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\(^1\) This rule is found also in \(SuSi\), iii. 1-4; \(BrSpSi\), iii. 1; \(Lbh\), iii. 1; \(ŚiDV\), I, iii. 1; \(MSi\), iv. 1-2; \(ŚiŚe\), iv. 1-3; and \(ŚiŚi\), I, iii. 8-9.

\(^2\) In general, as Parameśvara says in his comm. on \(Lbh\), iii-1-3 this radius may be any length greater than \((1/2) E_1W_1\).

\(^3\) Varāhamihira calls this figure “yava (barley or barley-figures) also.” See \(PSi\), iv. 19.
by him have been supplied by his commentator Prthūdaka Svāmi (860 A.D.).

The method of getting the correct east-west line is found to occur also in the Siddhānta-śekhara of Śripati (c. 1039 A.D.) the Siddhānta-śiromani of Bhāskara II (1150 A.D.) etc. For practical purposes, however, the method given in the text is good enough.

An alternative rule:

3. With the three points (at the ends of the three shadows of the gnomon) corresponding to (any three) different times (in the day), draw two fish-figures (each with two of the three points) in accordance with the usual method. From the point of intersection of the lines passing through the mouth and tail (of the two fish-figures), determine the north and south directions.

According to this rule, the north-south line is the one joining the foot of the gnomon with the point of intersection of the mouth-tail lines of the two fish-figures.

Varāhamihira states this rule as follows:

"Mark three times, from the centre, the end of the gnomon's shadow, and then describe two fish-figures. Thereupon describe a circle, taking for radius a string, that is fastened to the point in which the two strings issuing from the heads of the fish-figures intersect, and that is so long as to reach the three points marked. On the given day the shadow of the gnomon moves in that circle, without departing from it.

"The line joining the centre of that circle and the base of the gnomon is the south-north line; and the interval in north direction (between that circle and the gnomon) is the midday shadow." 

1 See Sudhākara Dvivedi's comm. on Br Śp Si, iii. 1.
2 iv. 14-16.
3 I, iii. 8.
4 This point of intersection is the same as the centre of the circle passing through the three shadow-ends.
5 This rule is found also in PSi, xiv. 14-16; Br Śp Si, iii. 2; Śi D Vr, I, iii. 2; and Śi Śe, iv. 4.
Brahmagupta is more precise. He says:

"The point where the lines passing through the two fish-figures, which are drawn by means of three shadow-ends (of the gnomon), intersect each other is, for places in the northern hemisphere, the south direction* (if the midday shadow falls to the north of the foot of the gnomon). If the midday shadow falls towards the south of the foot of the gnomon, it is the north direction".  

The above rule is evidently based on the assumption that the locus of the end of the shadow of the gnomon is a circle. In fact, for places whose latitudes are less than 90°—(where is the obliquity of the ecliptic), this locus is a hyperbola, so the above assumption is not a correct one. The above rule will, however, give an approximately correct result if the three shadow-ends chosen are not far removed from the vertex of the hyperbola.

The method of drawing a circle through three given points by the aid of two fish-figures is called "triśarkarā-vidhāna" by Bhāskara I.  

A rule for getting the length of the hypotenuse of the shadow:

4. The square root of the sum of the squares of the gnomon and its shadow (is equal to the hypotenuse of the shadow: this), say the learned (astronomers), is always the semi-diameter of its own circle in the calculations with the shadow.

By "the semi-diameter of its own circle" is meant "the semi-diameter of the circle of shadow".

The circle of shadow is, as Bhāskara I has said, useful in the application of proportion in connection with the problems involving the shadow of the gnomon. For example, in finding out the Rsine of the Sun's zenith distance from the shadow of the gnomon, the proportion is:

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1 The north direction being indicated by the end of the midday shadow of the gnomon.
2 BrSpSi, iii. 2.
3 See LBh, vi. 16.
4 This rule is found also in Ã, ii. 14.
5 In his commentary on Ã, ii. 14.
6 Rsine stands for "radius × sine".
"When to the radius of the circle of shadow corresponds the shadow of the gnomon, what will correspond to the radius of the celestial sphere? The result is the Rsine of the Sun’s zenith distance”.

Rules for finding the latitude and colatitude and the zenith distance and altitude of the Sun:

5. Multiply the radius by (the length of) the shadow and (at another place) by (the length of) the gnomon. Divide (the two results) separately by the square root (obtained above). When this calculation is performed for an equinoctial midday, the (two) results denote the Rsine of the latitude and the Rsine of the colatitude (respectively); elsewhere, they denote the great shadow (i.e., the Rsine of the Sun’s zenith distance) and the great gnomon (i.e., the Rsine of the Sun’s altitude) (respectively).¹

That is

\[ \text{Rsin } \phi = \frac{\text{equinoctial midday shadow } \times \text{ radius}}{\text{hypotenuse of equinoctial midday shadow}}, \]

\[ \text{Rsin } C = \frac{\text{gnomon } \times \text{ radius}}{\text{hypotenuse of equinoctial midday shadow}}, \]

and

\[ \text{Rsin } z = \frac{\text{shadow } \times \text{ radius}}{\text{hypotenuse of shadow}}, \]

\[ \text{Rsin } a = \frac{\text{gnomon } \times \text{ radius}}{\text{hypotenuse of shadow}}, \]

where \( \phi \) and \( C \) denote the latitude and colatitude of the place, and \( z \) and \( a \) denote the zenith distance and altitude of the Sun.²

These results are easily proved by assuming that the rays coming from the Sun are parallel.

¹ This rule is found also in ŚūSi, iii. 13-14; Br.SpSi, iii. 10; LBh, iii. 2-3; ŚiDVr, I, iii. 4-5; ŚiŚe, iv. 7; and ŚiŚi, I, iii. 18.

² The equinoctial midday shadow is the shadow cast by the gnomon at midday at an equinox.
In fact, however, the rays coming from the Sun are not exactly parallel, so that the angle between the gnomon and the Sun's ray reaching the ground through the upper end of the gnomon is not exactly equal to the zenith distance of the Sun. Moreover, the shadow which is actually measured is the umbra (i.e., the shadow between the foot of the gnomon and the point where the ray coming from the uppermost point of the Sun's disc and passing through the upper end of the gnomon meets the ground) and not the theoretical shadow corresponding to the central ray of the Sun coming through the upper end of the gnomon. Later Hindu astronomers have, therefore, prescribed corrections to the results determined according to the rules in the above stanza.¹

For practical purposes the rules stated above are good enough. The error is negligible.

Rules for determining the declination, day-radius, earthsine, and ascensional difference (for the Sun or a point on the ecliptic):

6-7. Multiply the Rsine of the given longitude by 1397 and always divide by the radius; the result is the Rsine of the declination for that time. Subtract the square of that (Rsine of the declination) from the square of the radius and then take the square root (of the difference); the result is called the day-radius.² Multiply the Rsine of the latitude by (the Rsine of) the given declination and divide by (the Rsine of) the colatitude: the result is the earthsine.³ Multiply the earthsine by the radius and then divide (the product) by the day-radius; then reduce (the resulting Rsine) to arc. Whatever (arc) is thus obtained is termed "the ascensional difference" by the best amongst the good (astronomers).⁴

¹ These corrections occur in KPr, iv. 2; KP, viii. 3; and TS, iii. 10(ii)-11.
² This rule is found also in S Si, ii. 28; BrSpSi, ii. 55; LBh, ii. 16; ŠIDVr, i.ii. 17; SiŠe, iii. 63-64; SiŠi, i. ii. 47(ii).
³ This rule is found also in A, iv. 24; BrSpSi, ii. 56; LBh, ii. 17; ŠIDVr, i, ii. 18; SiŠe, iii. 66; SiŠi, i. ii. 48.
⁴ This rule is found also in A, iv. 26; LBh, ii. 17-18; SiŠe, iii. 65.
⁵ This rule is found also in ŠuŠi, ii. 61; BrSpSi, ii. 57-58; LBh, ii. 18; ŠIDVr, i, ii. 18; SiŠe, iii. 67 (i); SiŠi, i, ii. 49 (i).
That is

(1) $\text{Rsin} \delta = \frac{1397 \times \text{Rsin} \lambda}{R}$,

(2) Day-radius $= \sqrt{R^2 - (\text{Rsin} \delta)^2}$,

(3) Earthsine $= \frac{\text{Rsin} \phi \times \text{Rsin} \delta}{\text{Rsin} (90^\circ - \phi)}$,

(4) $\text{Rsin (ascensional difference)} = \frac{\text{earthsine} \times \text{radius}}{\text{day-radius}}$,

where $R$ is the radius, $\phi$ is the latitude of the place, and $\lambda$ and $\delta$ are the $s\ddot{a}yana$ longitude$^1$ and declination respectively.

Definitions.

The day-radius is the radius of the small circle parallel to the celestial equator. A small circle parallel to the celestial equator is called a diurnal circle ($ahor\ddot{a}tra-vrtta$). In particular, the Sun’s diurnal circle is the small circle parallel to the equator which the Sun describes in the course of a day.

The earthsine is the Rsine of the arc of a diurnal circle intercepted between the local horizon and the six o’clock circle.$^2$ In Hindu astronomy, the six o’clock circle is called the equatorial horizon ($niraksa$-$ks\ddot{a}tiya$) as it is the horizon of a place$^3$ on the equator.

The ascensional difference is defined by the arc of the celestial equator lying between (i) the equatorial horizon and (ii) the secondary to the equator passing through the intersection of the diurnal circle and the (eastern or western) horizon. It is measured in time (i.e., in $asu^4$).

The ascensional difference of the Sun thus denotes the difference between the times of rising of the Sun on the local and equatorial horizons.

---

$^1$ By the $s\ddot{a}yana$ longitude is meant the celestial longitude measured from the moving vernal equinox.

$^2$ The six o’clock circle is the great circle of the celestial sphere which passes through the east and west points of the celestial horizon and the poles of the celestial equator.

$^3$ This place lies at the intersection of the local meridian and the equator.

$^4$ One $asu$ corresponds to one minute of arc of the celestial equator. Thus one $asu = 4$ seconds of sidereal time.
Rationale of the above rules.

(1) In Fig. 4, let $S$ be the Sun (or a point on the ecliptic), $SL$ the perpendicular from $S$ on the plane of the celestial equator, and $SM$ the perpendicular from $S$ on the line joining the centre of the celestial sphere with the first point of Aries. Then in the plane triangle $SLM$, we have

$$SL = R \sin \delta,$$
$$SM = R \sin \lambda,$$
$$\angle SML = \zeta,$$
and $\angle SLM = 90^\circ$.

Therefore, $SL/SM = R \sin \zeta / R \sin 90^\circ$,
or $R \sin \delta = \frac{R \sin \zeta \times R \sin \lambda}{R}$
$$= \frac{1397 \times R \sin \lambda}{R}, \text{ for } R \sin \zeta = 1397.1.$$ 

(2) The arcual distance of the diurnal circle from the north pole of the celestial equator $= 90^\circ - \delta$. Therefore, the day-radius $= R \sin (90^\circ - \delta)$, or $\sqrt{R^2 - (R \sin \delta)^2}$.

(3) In Fig. 5, let $K$ be the point of intersection of the diurnal circle and the six o'clock circle, $KB$ the perpendicular from $K$ on the rising-setting line, and $KA$ the perpendicular from $K$ on the east-west line. Then in the plane triangle $KAB$, we have

$$KA = R \sin \delta,$$
$$KB = \text{ earthsine},$$
$$\angle KBA = 90^\circ - \phi,$$
and $\angle KAB = \phi$.

---

1 See LBh, ii. 16.

2 The rising-setting line of a heavenly body is the line joining the point where the heavenly body rises on the eastern horizon with the point where it sets on the western horizon. In other words, it is the line of intersection of the planes of the celestial horizon and the diurnal circle.
Therefore, we have

\[
\frac{\text{earthslne}}{\text{Rsin } \delta} = \frac{\text{Rsin } \phi}{\text{Rsin } (90^\circ - \phi)}
\]

or

\[
\text{earthslne} = \frac{\text{Rsin } \phi \times \text{Rsin } \delta}{\text{Rsin } (90^\circ - \phi)}
\]

(4) By definition

\[
\frac{\text{Rsin (asc. diff.)}}{\text{earthslne}} = \frac{\text{radius}}{\text{day-radius}}
\]

Therefore

\[
\text{Rsin (asc. diff.)} = \frac{\text{earthslne} \times \text{radius}}{\text{day-radius}}
\]

A rule for finding the ascensional differences of the (sāyana) signs Aries, Taurus, and Gemini:

8. Twenty-four multiplied by ten (i.e., 240), 192, and 81—these when (successively) multiplied by the aṅgulas of the equinoctial midday shadow and (the products thus obtained) divided by four become the asus of the ascensional differences corresponding to Aries, Taurus, and Gemini respectively.¹

The numbers 240, 192, and 81 given above are four times the ascensional differences in asus of the signs, Aries, Taurus, and Gemini respectively for a place having one aṅgula for the equinoctial midday shadow.

We have seen that the ascensional difference of the Sun is the difference between the times of rising of the Sun on the local and equatorial horizons. The ascensional difference of the sign Aries is the difference between the times that the sign Aries takes in rising above the local and equatorial horizons. Since the first point of Aries rises simultaneously at both the horizons, therefore the ascensional difference of Aries is equal to the ascensional difference of the last point of Aries (for which \( \lambda = 30^\circ \)). Similarly, the ascensional difference of Aries and Taurus (taken together) is equal to the ascensional difference of the last point of Taurus (for which \( \lambda = 60^\circ \)).

The ascensional difference of Taurus is equal to the ascensional difference of Aries and Taurus minus the ascensional difference of Aries.

¹ Similar rules occur also in PSi, iii. 10; KK (Sengupta), i. 21; KK (Babua Misra), iii. 1; ŚiDVṛ, I, xiii. 9; SiŚi, I, ii. 50-51.
That is to say, it is equal to the ascensional difference of the last point of Taurus minus the ascensional difference of the first point of Taurus.

The ascensional difference of Gemini, similarly, is equal to the ascensional difference of the last point of Gemini minus the ascensional difference of the first point of Gemini.

The following is the rationale of the above rule:

From stanza 7, we have

\[ R \sin \text{(asc. diff.)} = \frac{R \sin \phi \times R \sin \delta}{R \sin (90^\circ - \phi)} \times \frac{\text{radius}}{\text{day-radius}}. \]

But from stanza 5, assuming gnomon = 12 aṅgulas,

\[ \frac{R \sin \phi}{R \sin (90^\circ - \phi)} = \frac{\text{equinoctial midday shadow}}{12}. \]

Therefore

\[ R \sin \text{(asc. diff.)} = \frac{(\text{equinoctial midday shadow}) \times R \sin \delta \times \text{radius}}{12 \times R \cos \delta}. \]

Hence for a place having one aṅgula for the equinoctial midday shadow

\[ R \sin \text{(asc. diff.)} = \frac{R \sin \delta \times R}{12 \times R \cos \delta} \]

\[ = \frac{1397 \times R \sin \lambda}{R} \times \frac{R}{12 \times R \cos \delta}, \text{ (using stanza 6)} \]

where \( \lambda \) is the sāyana longitude, \( \delta \) the declination, and \( R \) the radius (=3438').

Now we will calculate the ascensional differences of Aries, Taurus, and Gemini for a place having one aṅgula for the equinoctial midday shadow.

(1) Calculation of the ascensional difference of Aries.
At the last point of Aries, \( \lambda = 30^\circ \), so that \( R \sin \lambda = R/2 \).
Therefore, \( R \sin \delta = 1397/2 = 698' \cdot 5 \)
and \( R \cos \delta = 3366' \).
Hence $R\sin$ (asc. diff. of Aries)

\[
\frac{698.5 \times 3438}{3366 \times 12} = \frac{2401443}{40392} \approx 60' \text{ approx.}
\]

Therefore, the ascensional difference of Aries is 60 asus approximately.

(2) Calculation of the ascensional difference of Taurus.

At the last point of Taurus, $\lambda = 60^\circ$, so that

$R\sin \lambda = 2977'$.

Therefore, $R\sin \delta = 1210'$ approx.

and $R\cos \delta = 3218'$ approx.

Hence $R\sin$ (asc. diff. of Aries and Taurus)

\[
\frac{1210 \times 3438}{12 \times 3218} \approx 108' \text{ approx.}
\]

Therefore, the ascensional difference of Aries and Taurus is 108 asus. Subtracting from it the ascensional difference of Aries, the ascensional difference of Taurus comes out to be 48 asus.

(3) Calculation of the ascensional difference of Gemini.

At the last point of Gemini, $\lambda = 90^\circ$, so that $R\sin \lambda = R$.

Therefore, $R\sin \delta = 1397'$ and $R\cos \delta = 3141'$.

Hence $R\sin$ (asc. diff. of Aries, Taurus, and Gemini)

\[
\frac{1397 \times R}{12 \times 3141} \approx \frac{4802886}{37692} \approx 128' \text{ approx.}
\]
It follows that the ascensional difference of Aries, Taurus, and Gemini (taken as a whole) is $128 \text{ asus}$. Subtracting from it the ascensional difference of Aries and Taurus, we get $20 \text{ asus}$. This is the ascensional difference of Gemini.$^1$

The formula for the ascensional difference may now be written as

$$
R\sin (\text{asc. diff.}) = R\sin (\text{asc. diff. for unit equinoctial midday shadow}) \times (\text{equinoctial midday shadow}).
$$

or

$$
\text{asc. diff.} = \frac{[4 \times (\text{asc. diff. for unit equinoctial midday shadow})]}{4}
$$

approximately. Hence the above rule.

A rule for finding the times of rising of the ($sāyana$) signs at the equator:

9. (Severally) multiply the Rsines of (one, two, and three) signs by $3141$ and divide (each of the products) by the corresponding day-radius. Reduce the resulting Rsines to the corresponding arcs, and then diminish each arc by the preceding arc (if any). The residues obtained after subtraction are the times (in $\text{asus}$) of rising of the signs Aries, Taurus, and Gemini at the equator.$^2$

---

$^1$ We have taken above the approximate values of the ascensional differences of the last points of Aries, Taurus, and Gemini. Better values are $59\cdot45$, $107\cdot77$ and $127\cdot4 \text{ asus}$. If these values are taken, then the ascensional differences of Aries, Taurus, and Gemini would come out to be $59\cdot45$, $48\cdot32$, and $19\cdot63 \text{ asus}$. Four times of these are $238$, $193$ and $79 \text{ asus}$ approx. Hence some astronomers (see Paramesvara’s *Siddhānta-dīpikā*) give the following reading of the text:

वसुविद्या (२३८) मुणाद्रभुमो (१९३)

नवाधि (७९)श्चाँचित्तात: पताङ्गलेः

कुतस्वभि: कित्योम्याल्लिजः

श्रवासव: श्यु: कमचस्तु वापिता: $

$^2$ This rule is found also in *SiSi*, iii. 42-43; *BrSpSi*, iii. 15; *ŚiDVr*, I, iii. 8; *SiSe*, iv. 15; *SiŚi*, I, ii. 51.
If $A$, $B$, and $C$ be the last points of the signs Aries, Taurus, and Gemini respectively, then the time of rising of Aries at the equator is equal to the right ascension of $A$, the time of rising of Taurus at the equator is equal to the right ascension of $B$ minus the right ascension of $A$, and the time of rising of Gemini at the equator is equal to the right ascension of $C$ minus the right ascension of $B$.

If $\lambda$ and $\delta$ be the $\text{sāyana}$ longitude and declination of a point on the ecliptic, then the right ascension $\alpha$ of that point is given by the formula:

$$R\sin \alpha = \frac{R \cos \zeta \times R \sin \lambda}{R \cos \delta},$$

where $\zeta$ is the obliquity of the ecliptic.

But, according to Bhāskara I, $\zeta = 24^\circ$; therefore we have

$$R \sin \alpha = \frac{3141 \times R \sin \lambda}{\text{day-radius}}.$$

Hence the above rule.

Times of rising of the ($\text{sāyana}$) signs, Aries, Taurus, and Gemini at the equator and a rule for finding the times of rising of the ($\text{sāyana}$) signs at the local place:

10. Those who know astronomical methods have found them (i.e., the times of rising of Aries, Taurus, and Gemini at the equator) to be 1670, 1795, and 1935 ($\text{asus}$ respectively). These respectively diminished and the same reversed and increased by the corresponding ascensional differences are the times (in $\text{asus}$) of rising of the six signs beginning with Aries at the local place. (The same in the inverse order are the times of rising of the six signs beginning with Libra at the local place.)

If $a$, $b$, and $c$ denote the ascensional differences of Aries, Taurus and Gemini respectively, then the times of rising of the signs at the local place are given by the following table:

---

1 This formula occurs in $\bar{A}$, iv. 25. For its rationale see Part I, Chapter IX.

2 See $LBh$, ii. 16, where $R \sin \zeta$ has been stated to be equal to 1397$'$.

3 This rule occurs also in $SūSi$, iii. 43-45; $LBh$, iii. 5-6; $ŚiDVṛ$, i, iii. 9; $SiŚe$, iv. 17, 15(ii); $SiŚi$, i, iii. 58-59(i).
### Times of Rising of the Signs at the Local Place

<table>
<thead>
<tr>
<th>Sign</th>
<th>Time of rising at the local place, in asus</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Aries</td>
<td>1670 — a</td>
<td>12 Pisces</td>
</tr>
<tr>
<td>2 Taurus</td>
<td>1795 — b</td>
<td>11 Aquarius</td>
</tr>
<tr>
<td>3 Gemini</td>
<td>1935 — c</td>
<td>10 Capricorn</td>
</tr>
<tr>
<td>4 Cancer</td>
<td>1935 + c</td>
<td>9 Sagittarius</td>
</tr>
<tr>
<td>5 Leo</td>
<td>1795 + b</td>
<td>8 Scorpio</td>
</tr>
<tr>
<td>6 Virgo</td>
<td>1670 + a</td>
<td>7 Libra</td>
</tr>
</tbody>
</table>

A rule for the determination of the meridian zenith distance and meridian altitude of the Sun with the help of the Sun’s declination and the latitude of the place:

11. The difference or the sum of the Sun’s declination and the latitude (of the place) according as the Sun is in the six signs beginning with Aries or in the six signs beginning with Libra is the Sun’s meridian zenith distance (i.e., the zenith distance of the midday Sun).\(^1\)

90 degrees (literally, a quadrant of a circle) minus the degrees of the (Sun’s) meridian zenith distance is the (Sun’s) meridian altitude.\(^2\)

The Rsine of the degrees of the Sun’s meridian zenith distance is the great shadow; and the other (i.e., the Rsine of the Sun’s meridian altitude) is the great gnomon.

An alternative rule for finding the Sun’s meridian altitude:

12. Or, take the Sum or difference of the earthsine and the day-radius according as the Sun is in the northern or southern

---

\(^1\) This rule is found also in BrSpSi, iii. 47; LBh, iii. 27; ŚiDVṛ, I, iii. 16; SiSe, iv. 42(i).

\(^2\) This rule is found also in BrSpSi, iii. 47(ii); SiSe, iv. 42(ii).
hemisphere; then multiply that (sum or difference) by (the Rsine of) the colatitude and divide by the radius. The result thus obtained is the Rsine of the Sun’s altitude at midday.

Let S (See Fig. 6) be the position of the midday Sun on the celestial sphere. Also let SA and SB be the perpendicul ars dropped from S on the plane of the celestial horizon and the Sun’s rising-setting line¹ respectively. Then in the plane triangle SAB, we have

\[
\begin{align*}
SA &= R \sin a \\
SB &= \text{day-radius } \pm \text{ earthsine,}
\end{align*}
\]

\[\angle SBA = 90° - \phi,\]

and \[\angle SAB = 90°,\]

where \(a\) denotes the Sun’s altitude, and \(\phi\) the latitude of the place.

Therefore \[\frac{SA}{SB} = R \sin \angle SBA / R \sin \angle SAB,\]

or \[R \sin a = \frac{(\text{day-radius } \pm \text{ earthsine}) \times R \sin (90° - \phi)}{R},\]

+ or − sign being taken according as the Sun is to the north or south of the equator.

A rule for determining the Sun’s declination with the help of the Sun’s meridian zenith distance and the latitude of the local place, when the latitude is greater than the Sun’s meridian zenith distance:

13. When the latitude is greater than the arc of the Sun’s meridian zenith distance derived from the (midday) shadow (of the gnomon), their difference is the declination of the apparent Sun. The Sun is also, in that case, in the northern hemisphere.²

This rule relates to the case when the midday shadow of the gnomon falls to the north of the gnomon.

¹ Vide supra, p. 64 (footnote).
² This rule is found also in LBh, iii. 30.
A rule for determining the Sun’s declination with the help of the Sun’s meridian zenith distance and the latitude of the local place, when the midday shadow of the gnomon falls to the south of the gnomon:

14. When the (midday) shadow (of the gnomon) falls to the south (of the gnomon), then the sum of the latitude and the Sun’s true meridian zenith distance gives the declination of the Sun lying in the northern hemisphere.¹

A rule for finding the Sun’s declination with the help of the latitude and the Sun’s meridian zenith distance, when the Sun’s meridian zenith distance is greater than the latitude and the shadow of the gnomon falls towards the north of the gnomon:

15. When the Sun’s meridian zenith distance is greater than the latitude, then the latitude is always subtracted from that (i.e., from the Sun’s meridian zenith distance): the remainder (obtained) after subtraction denotes the Sun’s true declination. The Sun is also, in that case, undoubtedly in the southern hemisphere.²

The rules in the above three stanzas may be summarised as follows:

(1) When the midday shadow of the gnomon falls towards the north of the gnomon, then

Sun’s declination = latitude − Sun’s meridian zenith distance,

the Sun’s declination being north or south according as the latitude is greater or less than the Sun’s meridian zenith distance.

(2) When the midday shadow of the gnomon falls towards the south of the gnomon, then

Sun’s declination = latitude + Sun’s meridian zenith distance,

the Sun’s declination in this case being always north.

¹ This rule is found also in LBh, iii. 30.
² This rule is found also in LBh, iii. 31.
A rule for the determination of the Sun's longitude from its declination:

16. The radius multiplied by the Rsine of that (Sun's declination) should be divided by the Rsine of the Sun's greatest declination. The resulting Rsine reduced to arc, or (90° minus that arc) increased by three signs, or that (arc) increased by six signs, or (90° minus that arc) increased by nine signs, according as the Sun is in the first, second, third, or fourth quadrant, is the Sun's longitude.¹

The longitude thus obtained is sāyana.

In the above rule a knowledge of the Sun's quadrant is assumed, but nowhere in the present work are we told how to know the Sun's quadrant. From other works on Indian astronomy we learn that it was known from the nature of the midday shadow. In the Pitāmaha-siddhānta² we are given the following criteria for knowing whether the Sun is in the first, second, third, or fourth quadrant:

“(When the Sun is) in the first quadrant, the (midday) shadow of the trees is smaller than the equinoctial midday shadow and also decreasing (day to day); in the second quadrant, it is smaller (than the same) but increasing; in the third quadrant, it is greater and also increasing; and in the fourth, it is greater but decreasing”.

So also says Śrīpati³, but (for places below the Tropic of Cancer) he adds:

“If the (midday) shadow fall towards the south and be on the increase, even then the quadrant is the first. Similarly, if you see that the (midday) shadow (falling towards the south) is on the decrease, you must understand that the quadrant is the second.”⁴

¹ This rule occurs also in ŚūŚi, iii. 18-19; and LBh, iii. 32-33.
² This work is in prose and was edited along with a few other siddhāntas in the Joytisha-siddhānta-saṅgraha by Pandit Vindhyeshwari Prasad Dwivedi, Banaras (1912).
³ ŚīŚe, iv. 70.
⁴ ŚīŚe, iv. 71.
Kamalākara has followed Śrīpati. Parameśvara has also made a similar statement. He says:  

"The Sun’s northern or southern hemisphere (gola) and the Sun’s northerly or southerly course (ayana) should be determined from the point where the Sun rises and from the decrease or increase of the (midday) shadow (of a gnomon) on two consecutive days". 

Certain astronomers decided the Sun’s quadrant on the basis of the seasons. For example, Bhāskara II writes:

"The quarters of the year are known from the characteristics of the seasons, so I will describe them afterwards".

A rule for the determination of the latitude with the help of the Sun’s meridian zenith distance and declination:

17. When the Sun is in the northern hemisphere (and the shadow of the gnomon falls towards the north), add the (Sun’s) declination and the (Sun’s) meridian zenith distance; when the Sun is in the southern hemisphere, or when the (midday) shadow (of the gnomon) falls towards the south (of the gnomon), take their difference: the sum or difference thus obtained is the latitude.

A rule for finding the Rsine of the Sun’s altitude or zenith distance from the time elapsed since sunrise in the forenoon or from the time to elapse before sunset in the afternoon:

18-20. Add the (Sun’s) ascensional difference derived from the local latitude to or subtract that from the asus (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon) according as the Sun is in the southern or northern

\[\text{1 See SiTV, iii. 192-193.} \]
\[\text{2 अर्कस्योदयसन्यात सातु दिनं योत्वोष्णु सन्यात्मानाभिभूति सन्यात्मान होताने वेदे।} \]
\[\text{3 See Parameśvara’s comm. on SūSī, ii. 19.} \]
\[\text{4 SiŚi, II, xi. 38.} \]
\[\text{5 This rule is found also in SūSī, iii. 15-16; BrSpSi, iii. 13; L Bh, iii. 34; SiŚē, iv.13.} \]
hemisphere. By the Rsine of that (sum or difference) multiply the day-radius and then divide (the product) by the radius. In the resulting quantity apply the earthsine reversely to the application of the ascensional difference (i.e., subtract the earthsine when the Sun is in the southern hemisphere and add the earthsine when the Sun is in the northern hemisphere). Then multiply that (i.e., the resulting difference or sum) by the Rsine of the colatitude of the local place and then divide (the product) by the radius again. Thus is obtained the Rsine of the Sun's altitude for the given time in ghaṭis.¹ The square root of the difference between the squares of the radius and that (Rsine of the Sun's altitude) is known as the (great) shadow.²

The asus elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon are obtained by multiplying the given ghaṭis³ by 360. These are equivalent to the number of minutes in the arc of the celestial equator lying between the hour circles passing through the Sun and through the Sun's position on the horizon at sunrise or sunset. When these asus are diminished or increased by the asus of the Sun's ascensional difference (according as the Sun is in the northern or southern hemisphere), the asus of the difference or sum correspond to the minutes lying in the arc of the celestial equator intercepted between the Sun's hour circle and the six o'clock circle. The Rsine of that multiplied by the day-radius and divided by the radius gives the distance in minutes of the Sun from the line joining the points of intersection of the six o'clock circle and the Sun's diurnal circle. That increased or diminished by the earthsine (according as the Sun is in the northern or southern hemisphere) gives the distance of the Sun from the rising-setting line.

In Fig. 7, let S be the position of the Sun on the celestial sphere, SA the perpendicular from S on the plane of the horizon, and SB the perpendicular from S on the rising-setting line. Then in the plane triangle SAB, we have

¹ This rule is found also in A, iv. 28; BrSpSi, iii. 25-26; LBh, iii. 7-10; SiDVr, I, iii. 24-25; SiŠe, iv. 32, 34; SiŠi, I, iii. 53-54.
² This rule is found also in BrSpSi, iii. 27(ii); and SiŠe, iv. 34.
$\text{SA} = R \sin a.$

$\text{SB} = \frac{R \sin (\text{given time in asus} \equiv \text{asc. diff.}) \times \text{day-radius}}{\text{radius}} \pm \text{earthsine},$

$\angle \text{SBA} = 90^\circ - \phi,$
and $\angle \text{SAB} = 90^\circ,$

where $a$ is the Sun's altitude, and

$\phi$ the latitude of the place.

Therefore, we have

$R \sin a = \frac{\text{SB} \times R \cos \phi}{R}.$

Hence the rule.

Fig. 7

An approximate rule for finding the Sun's altitude:

21. Multiply "the upright due to the instantaneous meridian-ecliptic point" by the Rsine of the degrees intervening between the Sun and the rising point of the ecliptic and then divide (the product) by the radius: the result is the Rsine of the Sun's true altitude. The square root of the difference between the squares of that and the radius is the Rsine of the Sun's zenith distance.

"The upright due to the meridian-ecliptic point" is the Rsine of the altitude of the meridian-ecliptic point.\(^1\) Therefore, the rule stated above may be expressed as

$$R \sin a = \frac{R \sin \theta \times R \sin (L - S)}{R},$$

where $a$ is the Sun's altitude, $\theta$ the altitude of the meridian-ecliptic point, $L$ the longitude of the rising point of the ecliptic, $S$ the longitude of the Sun, and $R$ the radius of the celestial sphere ($= 3438'$). The rising point of the ecliptic is that point of the ecliptic which lies on the eastern horizon.

This formula is approximate, because the distance between the rising point of the ecliptic and the meridian-ecliptic point is not always exactly equal to $90^\circ$ as assumed there.

\(^1\) See the next stanza.
The correct formula is

$$Rsin\ a = \frac{Rsin\ \psi \times Rsin\ (L-S)}{R},$$

where \( \psi \) denotes the altitude of the central ecliptic point.\(^1\)

The author does not prescribe this correct formula, because the value of \( Rsin\ \psi \) has not been accurately determined by him. In Chapter V he gives only an approximate formula for it.\(^2\)

For practical purposes the approximate formula is good enough.

Definition of "the upright due to the meridian-ecliptic point":"

22. The square root of the difference between the squares of the Rsine of the zenith distance of the meridian-ecliptic point and of the radius (\textit{ravi-kakṣyā}) is called "the upright due to the meridian-ecliptic point" by those who are well versed in Spherics.

Thus we see that "the upright due to the meridian-ecliptic point" is the Rsine of the altitude of the meridian-ecliptic point. It is usually called \textit{madhya-bāṅku}.

The word \textit{ravi-kakṣyā}, literally meaning "the Sun's orbit", is used in the text in the sense of "the radius (of the Sun's orbit)".

Two alternative rules for finding the Sun's altitude:

23–24. Increase or diminish the \textit{ghaṭīs} (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon) by the \textit{asus} of the (Sun's) ascensional difference (according as the Sun is in the southern or northern hemisphere). To the Rsine of that apply the Rsine of the (Sun's) ascensional difference reversely to the above. By what

\(^1\) The central ecliptic point (also called the "nonagesimal") is that point of the ecliptic which is 90 degrees behind the rising point of the ecliptic and 90 degrees ahead of the setting point of the ecliptic. This point of the ecliptic is at the shortest distance from the zenith and is the central point of that part of the ecliptic which lies above the horizon.

\(^2\) See \textit{infra}, Chapter V, verse 19.
is thus obtained multiply the product of the day-radius and (the Rsine of) the colatitude and then divide (the resulting product) by the square of the radius. The result of this (operation) is the Rsine of the (Sun’s) altitude.

Or, multiply the result obtained by the inverse application of Rsine of the (Sun’s) ascensional difference (in the above process) by the product of (the length of) the gnomon and the day-radius and then divide by the product of (the length of the hypotenuse of the equinoctial midday shadow and the radius; the result is the Rsine of the (Sun’s) altitude.\(^1\)

That is to say,

\[
\text{Rsine } a = \frac{M \times \text{day-radius}}{R} \times \frac{\text{Rcos } \phi}{R},
\]

where \(M = \text{Rsine (given } \text{ghatis asc. diff.)} \pm \text{Rsine (asc. diff.)}\), the upper or lower sign being taken according as the Sun is in the northern or southern hemisphere. \(a\) and \(\phi\) are, as usual, the Sun’s altitude and the latitude of the place respectively.

Or,

\[
\text{Rsine } a = \frac{M \times \text{day-radius}}{R} \times \frac{\text{gnomon}}{\text{hypotenuse of equinoctial midday shadow}}
\]

“\(M\) multiplied by day-radius and divided by radius” represents in the celestial sphere the perpendicular distance of the Sun from the rising-setting line.

A rule for finding the Sun’s altitude when the Sun’s ascensional difference is greater than the given time:

25. When the (Sun’s) ascensional difference (is greater than and) cannot be subtracted from the given \(\text{asus}\) (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon), subtract the latter from the former and with the Rsine of the remainder proceed as before (i.e., multiply, that by the day-radius and divide by the radius); then subtract the resulting

---

\(^1\) This rule occurs also in \(\text{BrSpSi, iii} 27(i); \text{SiDVr, I, iii} 27; \text{SiSe, iv} 37.\)
Rsine from the earthsine and then performing the usual process (i.e., multiplying that by the Rsine of the colatitude and dividing the product by the radius) determine the Rsine of the (Sun’s) altitude.\(^1\)

The case contemplated here arises when the Sun lies between the equatorial and local horizons, i.e., shortly after sunrise or before sunset.

A rule for finding the Sun’s altitude in the night:

26. In the night, the Rsine of the Sun’s altitude is to be obtained by applying the operations (of addition and subtraction) inversely, because the (laws of) addition and subtraction (of the Sun’s ascensional' difference and earthsine) in the night are contrary to those in the day.\(^2\)

The Rsine of the Sun’s altitude in the night is required (i) in the calculation of the elevation of lunar horns,\(^3\) and (ii) in the calculation of the solar eclipse.\(^4\)

The details of the method indicated in the above stanza have been explained by Parameśvara as follows:

"(When the Sun is) in the northern hemisphere, having calculated the Rsine of the given nocturnal asus (i.e., those elapsed since sunset in the first half of the night or those to elapse before sunrise in the second half of the night) as increased by the (Sun’s) ascensional difference, (then) multiplying (that) by the day-radius and dividing by the radius, (then) from the (resulting) quotient subtracting the earthsine, and (finally) multiplying the remainder by the Rsine of the colatitude and dividing by the radius is obtained the Rsine of the Sun’s altitude. (When the Sun is) in the southern hemisphere, the (Sun’s) ascensional difference and the earthsine are (respectively) subtractive and additive: this is the difference."\(^5\)

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\(^1\) This rule is found also in *Br.SpSi*. iii, 33; *LBh*, iii. 11; *ŚiDVṛ*, I, iii. 29; *ŚiŚe*, iv. 41.

\(^2\) This rule is found also in *Br.SpSi*, iii. 63; *LBh*, iii. 11; *ŚiŚe*, iv. 89.

\(^3\) See *Br.SpSi*, iii. 63.

\(^4\) See Parameśvara’s comm. on *LBh*, iii. 11.

\(^5\) Parameśvara’s comm. on *LBh*. iii. 11.
The Sun’s altitude for the night has been called पाताल-शाहकु by Brahmagupta.\textsuperscript{1}

Three rules for finding the time elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon when the Sun has a given altitude:

27-29. Multiply the Rsine of the Sun’s altitude derived from the given shadow (of the gnomon) by the radius and divide (the product) by (the Rsine of) the colatitude. Then subtract the minutes of the earthsine from or add them to the resulting quantity according as the Sun is in the six signs beginning with Aries or in the southern hemisphere. Multiply the resulting quantity by the radius and divide (the product) by the day-radius. To the corresponding arc apply the ascensional difference contrarily to the above: thus is obtained the number of asus (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon). These very same asus corresponding to the day to elapse (before sunset in the afternoon) or the day elapsed (since sunrise in the forenoon), when divided by 360, are declared to be the नादिस, etc., (of the required time).\textsuperscript{2}

Or, multiply the given Rsine of the Sun’s altitude by the square of the radius and divide by the product of the day-radius and (the Rsine of) the colatitude. To the result apply the Rsine of the (Sun’s) ascensional difference as before (i.e., subtract or add according as the Sun is in the northern or southern hemisphere). Then to the corresponding arc reversely apply the asus of the ascensional difference: the result obtained is again the number of asus (elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon.)

Or, multiply the Rsine of the Sun’s altitude by the hypotenuse of the equinoctial midday shadow and again by the

\textsuperscript{1} See BrSpSi, xv. 9.

\textsuperscript{2} This rule is found also in LBh, iii. 12-15 and in SiŚe, iv. 51-52.
radius and then divide (the resulting product) by the day-radius as multiplied by (the length of) the gnomon. From that the process for the determination of the (desired time in) nāḍīs is the same as before.

The first rule is the converse of the rule given in stanzas 18-20; the second rule is the converse of that given in stanza 23; and the third rule is the converse of that stated in stanza 24.

A rule for finding the longitude of the rising point of the ecliptic with the help of (i) the instantaneous sāyana longitude of the Sun and (ii) the civil time measured since sunrise, or with the help of (i) the Sun’s sāyana longitude at sunrise and (ii) the sidereal time elapsed since sunrise:

30-32. Multiply by the untraversed portion of (the sign occupied by) the Sun, the asus of the oblique ascension (i.e., the time, in asus, of rising at the local place) of that sign and divide (that product) by the number of degrees or minutes in a sign (i.e., by 30 or 1800) (according as the untraversed portion of the Sun’s sign is taken in degrees or minutes). Thus are obtained the asus of the oblique ascension of the untraversed portion of the sign occupied by the Sun. Subtract these from the given (time as reduced to) asus; and add the untraversed portion of the Sun’s sine to the Sun’s longitude (which is given). Then from the remaining asus subtract the asus of the oblique ascension of as many (succeeding) signs as possible; and add the same number of signs to the Sun’s longitude. Then multiply the outstanding residue of the given (time in) asus by 30 and divide (the product) by the asus of the oblique ascension of the next sign. Add the resulting degrees, etc., to the Sun’s longitude (obtained above). The resulting longitude is stated to be the (sāyana) longitude of the rising point of the ecliptic.

1 This rule is found also in ŚāSī, iii. 46-48; BrŚpŚi, iii. 18-20; LBh, iii. 17-19; ŚiDVṛ, I, iii. 11-12; ŚiŚe, iv. 18-19(i); ŚiŚi, I, iii. 2-4. The rising point of the ecliptic is that point of the ecliptic which lies on the eastern horizon.
It may be pointed out that the civil time elapsed since sunrise is equal to the sidereal time measured by the arc of the celestial equator lying between the hour circles which pass through the instantaneous position of the Sun and through the rising point of the ecliptic.

For greater accuracy in the result, Āryabhaṭa II (c. 950 A.D.) and Bhāskara II (1150 A.D.) prescribed the use of oblique ascensions of every 10 degrees of the ecliptic in place of those for every 30 degrees. Later on Muniśvara (1646 A.D.) and Kamalākara (1658 A.D.) prescribed the use of oblique ascensions of every degree of the ecliptic. Theoretically accurate method for getting the longitude of the rising point of the ecliptic was given earlier by the Kerala mathematician Nilakaṇṭha (1500 A.D.).

A rule for the determination of the longitude of the setting point of the ecliptic:

33. The longitude of the horizon-ecliptic point in the east increased by half a circle (i.e., by 180°) is the longitude of the setting point of the ecliptic. For, the time of setting of a sign is equal to the time taken in rising by the then rising sign.

Bhāskara II also says:

"The time in which a sign rises (above the horizon), is the same as that in which the seventh sign sets (below the horizon)."

A rule for obtaining the civil time measured since sunrise with the help of (i) the Sun's instantaneous sa'yana longitude and (ii) the sa'yana longitude of the rising point of the ecliptic, or the sidereal time elapsed since sunrise with the help of (i) the Sun's sa'yana longitude at sunrise and (ii) the sa'yana longitude of the rising point of the ecliptic:

34-36. Multiply the degrees of the traversed portion of the sign occupied by the rising point of the ecliptic by the

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1 His method occurs in TŚ, iii. 155(ii)-164(i).
2 i.e., the rising point of the ecliptic.
3 The setting point of the ecliptic is that point of the ecliptic which lies on the western horizon.
4 Cf. ŚiDVṛ, I, iii. 13(i); ŚiŚi, I, ii. 59(ii).
5 ŚiŚi, I, ii. 59 (ii).
oblique ascension of that sign and divide by 30, the resulting 
*asuš* denote the *asuš* of the oblique ascension of the traversed 
portion of the sign occupied by the rising point of the ecliptic. 
(Also subtract the traversed portion of the sign occupied by 
the rising point of the ecliptic from the longitude of the same 
point). Then from the resulting longitude subtract as many 
preceding signs as there are up to the Sun; and find out the 
*asuš* of the oblique ascensions of those signs. These *asuš* 
together with those (obtained above) when added with the 
*asuš* of the oblique ascension of the untraversed portion of the 
Sun’s sign give the *asuš* (elapsed since sunrise) in the day and 
(enable us to know) the *asuš* (elapsed since sunset) in the night. 
Dividing them by 6 and then by 60 are obtained the *ghaṭīs,* 
*vighaṭīs,* and *asuš* (of the time elapsed during the day or 
night).\(^1\)

This rule is the converse of that given in stanzas 30-32. It actually 
gives the method for finding the time elapsed since sunrise. When, 
therefore, the Sun’s longitude is given for sometime in the night and it 
is required to find the time elapsed since sunset, then the time elapsed since 
sunrise obtained according to the above rule should be diminished by the 
length of that day, or, as says the commentator Paramesvara, the given 
longitude of the Sun should be increased by six signs and then should be 
applied the above rule.

In case the given quantities be (i) the longitude of the rising point 
of the ecliptic and (ii) the Sun’s longitude at sunrise and the problem 
be to find out the civil time elapsed since sunrise, the above rule should 
be applied by treating the Sun’s longitude for sunrise as the first approxi-

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\(^1\) This rule is found also in *SīSi,* iii. 50-51; *BrSpSi,* iii. 21-23; *LBh,* 
iii. 20; *ŚiDVṛ,* I, iii. 13; *ŚiŚe,* iv. 19(ii)-22(i); *ŚiŚi,* I, iii. 5-7(i). The *ghaṭīs,* 
*vighaṭīs,* and *asuš* are related by the following relations:

\[1	ext{ *asuš* } = 4 \text{ seconds},\]
\[6 \text{ *asuš* } = \text{ 1 *vighaṭī* } (= 24 \text{ seconds}),\]
\[60 \text{ *vighaṭīs* } = 1 \text{ *ghaṭī* } (= 24 \text{ minutes}).\]
mation to the instantaneous longitude of the Sun. The process should then be repeated over and over again with the help of the successive approximations to the Sun's instantaneous longitude calculated after each round of the operation. The process should be continued until two successive approximations to the required time agree to asus.\(^1\)

It must be noted that the longitudes used in this and the preceding rule (stated in stanzas 30-32) are all sāyana.

A rule for the determination of the Rsines of the Sun's prime vertical altitude and zenith distance:

37-38. Multiply the Rsine of the (Sun's) greatest declination by the Rsine of the Sun's true (sāyana) longitude; then divide (the product) by the Rsine of the colatitude: the result is (the Rsine of) the agrā of the true Sun.\(^2\) When that (agrā) is less than the latitude and when the Sun is also in the northern hemisphere, multiply (the Rsine of the Sun's agrā) by (the Rsine of) the colatitude and then divide (the product) by the Rsine of the latitude: the result is the Rsine of the Sun's prime vertical altitude.\(^3\) The square root of the difference between the squares of that and the radius is the Rsine of the Sun's (prime vertical) zenith distance.\(^4\)

The Sun's agrā is the amplitude of the Sun at rising or setting. It is defined to be the arc of the celestial horizon lying between the east-west and rising-setting lines. That is to say, it is the arc of the celestial horizon lying between the east point and the point where the Sun rises or between the west point and the point where the Sun sets.

The Rsine of the Sun's agrā is equal to the distance between the east-west and rising-setting lines.

In Fig. 8, let S be the Sun on the prime vertical, SA and SB the perpendiculars from S on the east-west and rising-setting lines.

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\(^1\) Cf. BrSpSi, iii. 21-23; SiŚi, I, iii. 6(ii).

\(^2\) This rule occurs also in \(\overline{A}\), iv, 30; LBh, iii. 21; SiŚe, iv. 58.

\(^3\) This rule occurs also in \(\overline{A}\), iv. 31; BrSpSi, iii. 52; LBh, iii. 52.

\(^4\) Cf. LBh, iii. 22.
respectively, and C the point where SB meets the line joining the points of intersection of the Sun’s diurnal circle and the six o’clock circle. Naturally, SB is perpendicular to that line.

In the triangle ACB, we have

\[ AC = R \sin \delta, \]
\[ AB = R \sin (\text{Sun’s} \ agrā), \]
\[ \angle ABC = 90^\circ - \phi, \]
\[ \text{and} \ \angle ACB = 90^\circ, \]

where \( \delta \) is the declination of the Sun, and \( \phi \) the latitude of the place.

Therefore

\[ R \sin (\text{Sun’s} \ agrā) = \frac{R \sin \delta \times R}{R \cos \phi}. \]

But (\textit{vide} stanza 6 above)

\[ R \sin \delta = \frac{R \sin \lambda \times 1397}{R}. \]

Therefore

\[ R \sin (\text{Sun’s} \ agrā) = \frac{R \sin \lambda \times 1397}{R \cos \phi}. \] (1)

where \( \lambda \) is the Sun’s \textit{sāyana} longitude.

Now in the triangle SAB, right-angled at A, we have

\[ SA = R \sin a, \]
\[ AB = R \sin (\text{Sun’s} \ agrā), \]
\[ \text{and} \ \angle SBA = 90^\circ - \phi. \]

Therefore

\[ R \sin a = \frac{R \sin (\text{Sun’s} \ agrā) \times R \cos \phi}{R \sin \phi}, \] (2)

where \( a \) is the Sun’s altitude.

The necessary conditions for the existence of the prime vertical altitude of the Sun are: (i) that the Sun should be in the northern hemisphere, and (ii) that the Sun’s declination should be less than the latitude of the place. The condition laid down in the above rule that the Sun’s \textit{agrā} should be less than the latitude is incorrect. This error is, in fact, due to Āryabhaṭa I,\(^1\) whom the author is following in this work. But the

\(^1\) See \textit{A}, iv. 30-31.
author seems to be unaware of the error. For, in his later work, the *Laghu-Bhāskarīya*, he has rectified the error and has stated the condition correctly.

The above error of Āryabhaṭa I was noticed and criticised by Brahmagupta. The commentators of Āryabhaṭa I, however, have interpreted the above rule as conveying the correct meaning.

A rule for the determination of the time in *asus* to elapse before or elapsed since midday when the Sun is on the prime vertical, i.e., the time taken by the Sun in going from the prime vertical to the local meridian or *vice versa*:

39. Multiply the Rsine of the Sun’s longitude (when the Sun is on the prime vertical) by the Rsine of the (Sun’s) greatest declination and divide (the product) by the day-radius: by the result thus obtained multiply the Rsine of the colatitude and (then) divide by the Rsine of the latitude. Subtract the square of the resulting quantity from the square of the radius: the arc corresponding to the square root of that gives the *asus* (measured on the equator from the Sun’s hour circle) up to the meridian.

Let $m$ denote the minutes in the arc of the Sun’s diurnal circle intercepted between the Sun and the six o’clock circle, and $r \ (= R \cos \delta)$ the radius of the Sun’s diurnal circle. Then in Fig., SC = $rsin \ m$; so that from the triangle SCA, right-angled at C, we have

\[
\frac{SC}{CA} = \frac{R \sin \angle SAC}{R \sin \angle CSA}
\]

or,

\[
rsin \ m = \frac{R \sin \delta \times R \cos \phi}{R \sin \phi}
\]

\[
= \frac{R \sin \lambda \times R \sin \acute{\epsilon}}{R} \cdot \frac{R \cos \phi}{R \sin \phi}, \quad \text{(using stanza 6)}
\]

where $\lambda$, $\delta$ denote the Sun’s *sāyana* longitude and declination respectively, and $\phi$ denotes the latitude of the place; $\acute{\epsilon}$ is the Sun’s greatest declination.

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1 iii. 22.

2 See *BrSpSi*, xi. 22.
Therefore, the Rsine of the corresponding arc of the equator, i.e.,
\[ \text{Rsine } m = \frac{\text{Rsine } \lambda \times \text{Rsine } \xi}{r} \times \frac{\text{Rcos } \phi}{\text{Rsine } \phi}, \]

so that
\[ \text{Rsine } (90^\circ - m) = \sqrt{R^2 - (\text{Rsine } m)^2}. \]

Therefore,
\[ 5400' - m = \text{Rsine}^{-1} [\text{Rsine } (90^\circ - m)], \]

which gives the required time in \textit{asus}, because \( 5400' - m \) is the number of minutes in the arc of the equator lying between the Sun's hour circle and the local meridian.

An alternative rule:

40. Or, multiply the Rsine of the Sun's prime vertical zenith distance by the radius and divide by the day-radius. Then applying the method of finding out the arc (corresponding to a given Rsine), convert the resulting Rsine into (the corresponding) arc. Then reduce the \textit{asus} (thus obtained) to \( \text{nadir} \), etc. These lie between the (prime vertical) Sun and the meridian.

In Fig. 9, let \( S \) be the Sun on the prime vertical, \( B \) the centre of the Sun's diurnal circle, and \( A \) the point where the plane of the Sun's diurnal circle intersects the zenith-nadir line. Then in the plane triangle \( SAB \), we have

\[ \text{SAB} = \text{Rsine } z, \]
\[ \text{SB} = \text{day-radius}, \]
\[ \angle \text{SAB} = 90^\circ, \]

and \( \angle \text{SBA} \) = the angle between the Sun's hour circle and the local meridian, \( z \) being the Sun's zenith distance.

\[ = \text{arc of the equator intervening between the Sun's hour circle and the local meridian}. \]

Therefore, we have
\[ \text{Rsine } \angle \text{SBA} = \frac{\text{Rsine } z \times R}{\text{day-radius}}. \]
A rule for finding the Sun's longitude when the Sun is on the prime vertical:

41. Multiply the Rsine of the latitude by the Rsine of the prime vertical altitude derived from the shadow (of the gnomon) and always divide the product by the Rsine of the Sun's greatest declination; (then reduce the resulting Rsine to the corresponding arc). The arc thus obtained, or (the complement of) that arc increased by three signs is the longitude of the (prime vertical) Sun (according as the Sun is in the first or the second quadrant). This is in accordance with what (Ārya)bhaṭa has written.¹

That is to say, if λ and a be respectively the sāyana longitude and altitude of the Sun when it is on the prime vertical, and φ the latitude of the place, then

\[ \text{Rsine } \lambda = \frac{\text{Rsine } a \times \text{Rsine } \phi}{\text{Rsine } \xi} , \]

where ξ is the Sun's greatest declination.

The rationale of this rule is as follows: Referring to Fig. 8, we see that in the triangle SAC

\[ \text{SA} = \text{Rsine } a , \]
\[ \text{AC} = \text{Rsine } \delta , \]
\[ \angle \text{ACS} = 90^\circ , \]

and \[ \angle \text{ASC} = \phi . \]

Therefore

\[ \text{Rsine } \delta = \frac{\text{Rsine } a \times \text{Rsine } \phi}{\text{R}} . \] (1)

Also from stanza 6, we have

\[ \text{Rsine } \lambda = \frac{\text{Rsine } \delta \times \text{R}}{\text{Rsine } \xi} . \] (2)

Hence, eliminating Rsine δ between (1) and (2), we get

\[ \text{Rsine } \lambda = \frac{\text{Rsine } a \times \text{Rsine } \phi}{\text{Rsine } \xi} . \]

The next eleven stanzas relate to the determination of the locus of the end of the shadow of the gnomon.

¹ Cf. Lbh, iii. 24-25.
To determine at any given time three points lying on the locus of the shadow-end:

42-45. Determine the agrā and śāṅkvagra of the Sun and also the shadow (of the gnomon) for the desired time. Then take the sum of the two agrās (i.e., of agrā and śāṅkvagra) provided that they are of like direction¹; in the contrary case, take their difference. (This sum or difference is called the bhujā and its direction corresponds to that of the Sun from the prime vertical.) By that (sum or difference) multiply the shadow and divide (the product) by the Rsine of the Sun’s zenith distance (for that time). Whatever is thus obtained should be laid off from the centre in the contrary direction (i.e., contrary to the direction of the Sun from the prime vertical) within a circle (drawn on level ground and) marked with the directions. Through the fish-figure drawn about the point thus obtained stretch out a thread in the east and west directions (bothways) to a distance. Then take a thread equal in length to the shadow (of the gnomon) and lay it off from the centre obliquely (to meet the other thread). Mark the two points where the end of this thread meets (the other thread stretched out) in the east and west directions. At the end of the midday shadow take a third point.

The sum or difference of the agrā and śāṅkvagra² of the Sun denotes the distance of the Sun’s projection on the plane of the horizon from the east-west line. This is called the bhujā and its direction is the same as that of the Sun from the prime vertical. This multiplied by the length of the shadow of the gnomon and divided by the Rsine of the Sun’s zenith distance gives the distance of the end of the shadow of the gnomon from the east-west line. Suppose, for example, that the sun is towards the south of the prime vertical, and that the end of the shadow of the gnomon is at a distance d from the east-west line.

Let the circle in Fig. 10 be the one constructed on level ground with

¹ The agrā is north or south according as it is towards the north or south of the east-west line; the śāṅkvagra is always south.
² For agrā see supra stanzas 37-38, and for śāṅkvagra see infra stanza 54,
the foot of the gnomon as centre and any arbitrary radius. Let EW and NS be the east-west and north-south lines respectively. Then the construction stated in the text is as follows: From O, along ON, measure a distance $d$ and mark there a point, say X. Through X stretch a thread (or draw a line) parallel to EW. Let this be LM. Now from centre O and radius equal to the shadow of the gnomon draw an arc of a circle cutting LM at the points A and B. Then OA and OB are the positions of the threads, equal in length to the shadow of the gnomon, laid off obliquely from the centre. The two points thus obtained are A and B. If OC be the midday shadow of the gnomon, then the third point is C. The three points thus determined are A, B, and C.

A rule for determining the same three points when the directions are not known:

46-51. For one who does not know the directions with regard to the centre but wants to determine the directions and the locus of (the end of) the shadow (of the gnomon), I state the method such that (the end of) the shadow (of the gnomon) may not leave the periphery of the large circle distinctly drawn amidst the directions (representing the path of the shadow-end).

Calculate the Rsine of the Sun's zenith distance, the R sine of the Sun's altitude, and the śāṅkuvagra corresponding to the desired shadow; then take the difference or sum of the two agrās (i.e., of the śāṅkuvagra and the agrā) (according as they are of unlike or like directions). This (difference or sum) is the base, the Rsine of the Sun's zenith distance is the hypotenuse, and the square root of the difference between their squares is called the upright corresponding to the hypotenuse equal to the Rsine of the Sun's zenith distance. On multiplying these, upright and base, (severally) by the (length of the) shadow and dividing by the Rsine of the Sun's zenith distance are obtained
the values of the upright and the base (corresponding to the hypotenuse equal to the shadow of the gnomon). Now take straight bamboo scales of breadth equal to the diameter of the gnomon and of lengths equal to the base and the upright (obtained above) (and one equal to the shadow); and with their help construct an accurate framework instrument in the form of a rectangle or a (right-angled) triangle having the shadow (of the gnomon) for the hypotenuse. At the corner (where the base and the hypotenuse meet) fix a gnomon. Then put the instrument (on level ground) and rotate it (about the gnomon) until the shadow (of the gnomon) falls along the hypotenuse. Then having determined the directions (north and south, east and west) as indicated by the base and the upright, mark two points at the end of the shadow-hypotenuse (one towards the east and the other towards the west). At the end of the midday shadow, take the third point.

The above stanzas give the method for finding the points A, B, and C (see Fig. 10), when the lines EW and NS are not known. The method is as follows:

Construct a triangular frame of bamboo scales having its sides equal to those of the triangle AXO or a rectangular frame having its sides equal to those of the rectangle OXAY, and let a gnomon (having its diameter equal to the breadth of the bamboo scales) be fitted at O vertically to the frame.

Place the frame on level ground with the point O at the centre of a circle drawn on the ground and with the hypotenuse OA in coincidence with the shadow of the gnomon. Then OX is directed south to north and AX west to east. Draw the lines OX and AX on the ground and produce them bothways. With centre O and radius equal to OA, the shadow of the gnomon, draw an arc of a circle cutting the line AX at two points. These are the points A and B. The point C is obtained as before.

Construction of the locus of the end of the shadow of a gnomon:

52. Through all the three points (thus obtained) a circle is (then) drawn with the help of two fish-figures. The shadow (of the
gnomon) moves, like a spell-bound serpent, with its head (i.e., end) kept upon the periphery of that circle.\(^1\)

Lalla says:

"With the point of intersection of the head-tail lines (of the two fish-figures) as centre, draw a circle passing through the ends of the three shadows. (The end of) the shadow (of the gnomon) does not leave the periphery of that circle in the same way as a lady born in a noble family does not leave the traditions of her family."

Śrīpati (c. 1039 A.D.) writes:

"The (end of the) shadow of the gnomon erected at the centre of the circle does not leave the periphery of the circle drawn with the common point of the head and tail lines (of the two fish-figures) and passing through the three shadow-ends in the same way as a noble-minded person does not leave the path of righteousness."\(^2\)

The above rule was later criticised by Bhāskara II (1150 A.D.), who made the following remark:

"It is declared (by some astronomers) that the shadow of the gnomon moves on the circle passing through the ends of the three shadows made by the same gnomon (placed in the centre of the horizon), but this is wrong, and consequently the east-west and north-south lines, the latitude, etc., found by the aid of the circle just mentioned are also wrong."\(^3\)

Bhāskara II's criticism is proper. The locus of the end of the shadow of a gnomon will not be a circle as stated in the text unless the latitude of the place is 90\(^\circ\). The locus will be, in general, a conic section. For places whose latitudes are less than \(\xi\) (\(\xi\) being the obliquity of the ecliptic), in particular, this locus will be a hyperbola.

Alternative rules for finding the Sun's \(agṛā\) and the latitude of the place:

53. The square root of the sum of the squares of the

---

\(^1\) This rule occurs also in \(BrSpSi\), iii. 2-3; \(ŚiDVṛ\), i, iii. 3; \(SiŚe\), iv. 5; \(TS\), iii. 42(ii)-47.

\(^2\) \(ŚiDVṛ\), i, iii. 3.

\(^3\) \(SiŚe\), iv. 5.

\(^4\) L. Wilkinson, Translation of the Siddhānta-śiromaṇi (Golādhyāya, xi. 38(ii), Calcutta (1861), p.221. We have replaced the word "revolves" by "moves".

Rsine of the (Sun’s) declination and the earthsine for the desired time is (the Rsine of) the Sun’s agrā (for that time).

The earthsine multiplied by the radius and divided by (the Rsine of) the Sun’s agrā is the Rsine of the latitude.

That is

\[ \text{Rsine (Sun’s agrā)} = \sqrt{\left( \text{Rsine } \delta \right)^2 + \left( \text{earthsine} \right)^2}, \tag{1} \]

\[ \text{and } \text{Rsine } \phi = \frac{\text{earthsine} \times R}{\text{Rsine (Sun’s agrā)}}, \tag{2} \]

where \( \delta \) is the Sun’s declination and \( \phi \) the latitude of the place.

These results easily follow from the triangle ACB in Fig. 8.

A rule for the determination of the śāṅkvagra:

54. The Rsine of the altitude for the desired time multiplied by the Rsine of the latitude and divided by (the Rsine of) the colatitude is the śāṅkvagra, which is always south (of the rising-setting line).\(^1\)

The śāṅkvagra (of a heavenly body) is the distance of the projection of the heavenly body on the plane of the horizon from its rising-setting line. In Fig. 8, the line AB denotes the Sun’s śāṅkvagra. The śāṅkvagra is measured from the rising-setting line and is always to the south of that line. It is more commonly known a śāṅkutala.

In Fig. 8, we have

\[ \text{SA} = \text{Rsine } a, \]
\[ \text{AB} = \text{śāṅkvagra}, \]
\[ \angle \text{SAB} = 90^\circ, \]

and \( \angle \text{SBA} = 90^\circ - \phi \),

where \( a \) denotes the altitude, and \( \phi \) the latitude of the place. Therefore from the triangle SAB, we have

\[ \frac{\text{śāṅkvagra}}{\text{Rsine } a} = \frac{\text{Rsine } \phi}{\text{Rcos } \phi}, \]

which gives the formula stated in the text.

A rule for finding the equinoctial midday shadow:

55. Multiply the śāṅkvagra by 12 and divide by the Rsine of the altitude; the result is (the length of) the equinoctial

\(^1\) This rule occurs also in \( A \), iv. 29 and in \( LBh \), iii. 16.
(midday) shadow (of the gnomon). The details are being stated below.

We have proved above (stanza 54) that

\[
\frac{sāṅkvagra}{R \sin a} = \frac{\text{Rsine } \phi}{R \cos \phi}.
\]

Also, from stanza 5 above, we have

\[
\frac{R \sin \phi}{R \cos \phi} = \frac{\text{equinoctial midday shadow}}{12}.
\]

Therefore

\[
\text{equinoctial middayshadow} = \frac{sāṅkvagra \times 12}{R \sin a}.
\]

Method of finding the Sun's agrā by observation and deriving therefrom the sāṅkvagra and then the equinoctial midday shadow of the gnomon and the latitude or colatitude of the place:

56-60(i). One should erect a (circular) platform, as high as one's neck, with its floor in the same level, and its circumference graduated with the divisions of signs, degrees, etc., and bearing the marks of the directions. (Then standing) on the western side thereof, one, having undisturbed state of mind, should, with the line of sight passing through the centre of the circular base, make the observation of the Sun when (at sunrise) it appears clinging to the circumference, (and mark there a point). The (arcual) distance, measured along the circumference graduated with the marks of degrees, between the end of the line drawn eastwards (i.e., the east point) and the point where the Sun is observed is the arc of the Sun's agrā. The Rsine of that (arc) is (the Rsine of) the Sun's agrā. The minutes of the difference between that (Rsine of the Sun's agrā) and the Rsine of the Sun's meridian zenith distance are the minutes of the sāṅkvagra, provided that the Sun is in the southern hemisphere; when the Sun is in the northern hemisphere (and the shadow of the gnomon falls towards the north), the process is otherwise (i.e., the addition of the two). When, however, (the Sun being in the northern hemisphere) the
shadow (of the gnomon) due to the Sun falls towards the south, the Sun’s agrā minus the Rsine of the Sun’s meridian zenith distance is stated to be (the value of) the saṅkvagra. From that (saṅkvagra) determine the true value of the equinoctial midday shadow (of the gnomon),¹ and then calculate as before the latitude and colatitude (for the place).

A rule for finding the longitude of an unknown planet with the help of (i) the longitude of a known planet and (ii) the difference between the times of rising or setting of the known and unknown planets:

60(ii)-61. Having correctly ascertained in terms of nāḍikās (i.e., ghatīs) the difference between (the times of rising or setting or culmination of) the planets to be known and known, multiply those ghatīs by six. Thus are obtained the degrees (of the difference between the longitudes of the two planets). By those degrees diminish or increase the longitude of the known planet according as it is to the east or west of the planet to be known. This is stated by the learned people well versed in planetary motions (to be the method for getting the the longitude of the planet to be known).

This rule is approximate, as the inclinations of the orbits of the two planets to the ecliptic have been neglected and the ecliptic has been supposed to rise above the horizon uniformly at the rate of six degrees per ghatī (i.e., 15 degrees per hour).

(2) JUNCTION-STARS OF THE ZODIACAL ASTERISMS AND CONJUNCTION OF PLANETS WITH THEM.

Longitudes of the prominent stars of the nakṣatras:

62. In this way from (the known longitudes of) the planets or stars have been determined, at all places and at all times, the celestial longitudes of the (prominent) stars of the nakṣatras.

The nakṣatras are the twenty-seven zodiacal asterisms. In the following table we give a few details regarding these nakṣatras.

¹ Vide supra stanza 55.
## Names, Shapes, and Number of the Stars of the Nakṣatras

<table>
<thead>
<tr>
<th>Name</th>
<th>Shape¹</th>
<th>Number of stars as given by</th>
<th>Identification²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Varahamihira³</td>
<td>Brahmagupta⁴</td>
<td>Lalla⁴</td>
</tr>
<tr>
<td>Aśvini</td>
<td>Head of a horse</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bharani</td>
<td>Yoni⁶</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Kṛttikā</td>
<td>Razor</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Rohiṇi</td>
<td>Cart</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mr̥gaśirā</td>
<td>Head of a deer</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ādrā</td>
<td>Jewel</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Punarvasu</td>
<td>House</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Pusya</td>
<td>Arrow-head</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Aśleṣā</td>
<td>Wheel</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Maghā</td>
<td>House</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Pūrvā</td>
<td>Manca⁷</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Phālguṇi</td>
<td>Cot</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Uttarā</td>
<td>Hand</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

¹ *MuCi*, ii. 59-60.  
² *BrSaṁ*, xcvi. 1-2.  
³ *KK* (Sengupta's edition), x. 1-2.  
⁴ *Ratna-Koṣa*.  
⁶ i.e., the femal organ of generation.  
⁷ *Manca* means an elevated platform resting on columns,
<table>
<thead>
<tr>
<th>Name</th>
<th>Shape</th>
<th>Number of stars as given by</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Varāhamihira</td>
<td>Brahmagupta</td>
</tr>
<tr>
<td>Citrā</td>
<td>Pearl</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Svāti</td>
<td>Coral bead</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Viśākhā</td>
<td>An arched doorway</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Anurādhā</td>
<td>Heaps of offering to gods</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Jyeṣṭhā</td>
<td>Eardrop</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Mūla</td>
<td>Tail of a lion</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Pūrvāśādha</td>
<td>Tusk of an elephant</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Uttarāśādha</td>
<td>Maṅca</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Śravana</td>
<td>Three feet</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Dhanisthā</td>
<td>Drum</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Šatabhiṣak</td>
<td>Circle</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>Pūrva-Bhādrapada</td>
<td>Maṅca</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Uttarak-Bhādrapada</td>
<td>Pair</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Revati</td>
<td>Drum</td>
<td>32</td>
<td>1</td>
</tr>
</tbody>
</table>
Positions of the junction-stars of the asterisms (*naksatras*) in the twelve signs, Aries, etc:

63-66(i). In Aries, eight, twenty-seven; in Taurus, six, nineteen; in Gemini, two, ten; in the next sign (i.e., Cancer), two, fifteen, twenty-four; in Leo, eight and a half, twenty-one; in Virgo, four, twenty-three; in Libra, five, seventeen; in the next sign (i.e., Scorpio), two, twelve, eighteen; in Sagittarius, one, fourteen, twenty-seven; in Capricorn, fifteen, twenty-six; in Aquarius, seven, twenty-eight; in the last sign (i.e., Pisces), fifteen, thirty—these are the degrees of the positions (with reference to the signs) of the junction-stars of the *naksatras* beginning with Aśvini.

The prominent stars of the *naksatras* which were used in the study of the conjunction of the planets, especially the Moon, with them are called junction-stars (*yoga-tārā*). The study of the conjunction of the planets with the junction-stars was originally meant to verify the computed longitudes of the planets with a view to test the accuracy of and to make improvements, if necessary, in the astronomical theories on which those computations were based.

The longitudes of the junction-stars which have been enumerated in the text are, in some cases, slightly at variance with those given by the author in his subsequent smaller work, the *Laghu-Bhaṭkariya*. The differences are exhibited by the following table:

---

1 "Of the stars in each *naksatra*, those that are seen to be the brightest are the junction-stars." *KK* (Sengupta’s edition), x. 3(i). The author of the *Sūrya-siddhānta* gives the relative position of the junction-star in each *naksatra*, which facilitates their identification. See *SūSi*, viii. 16-21.
## Differences between the Longitudes of the Junction-Stars in the Two Works of Bhaskara I

<table>
<thead>
<tr>
<th>Junction-star of</th>
<th>Longitude given in</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mahā-Bhāskarīya</td>
<td>Laghu-Bhāskarīya</td>
</tr>
<tr>
<td>Aśvini</td>
<td>8°</td>
<td>8°</td>
</tr>
<tr>
<td>Bharanī</td>
<td>27°</td>
<td>26° 30'</td>
</tr>
<tr>
<td>Kṛttikā</td>
<td>1° 6°</td>
<td>1° 6°</td>
</tr>
<tr>
<td>Rohinī</td>
<td>1° 19°</td>
<td>1° 20°</td>
</tr>
<tr>
<td>Mrgasirā</td>
<td>2° 2°</td>
<td>2° 2°</td>
</tr>
<tr>
<td>Ārdrā</td>
<td>2° 10°</td>
<td>2° 10°</td>
</tr>
<tr>
<td>Punarvasu</td>
<td>3° 2°</td>
<td>3° 2°</td>
</tr>
<tr>
<td>Pusya</td>
<td>3° 15°</td>
<td>3° 15°</td>
</tr>
<tr>
<td>Āśleṣā</td>
<td>3° 24°</td>
<td>3° 24°</td>
</tr>
<tr>
<td>Maghā</td>
<td>4° 8° 30'</td>
<td>4° 8° 30'</td>
</tr>
<tr>
<td>Pūrvā Phālgunī</td>
<td>4° 21°</td>
<td>4° 21°</td>
</tr>
<tr>
<td>Uttarā Phālgunī</td>
<td>5° 4°</td>
<td>5° 4°</td>
</tr>
<tr>
<td>Hasta</td>
<td>5° 23°</td>
<td>5° 23°</td>
</tr>
<tr>
<td>Citrā</td>
<td>6° 5°</td>
<td>6° 5°</td>
</tr>
<tr>
<td>Svāti</td>
<td>6° 17°</td>
<td>6° 17°</td>
</tr>
<tr>
<td>Viśākhā</td>
<td>7° 2°</td>
<td>7° 2°</td>
</tr>
<tr>
<td>Anurādhā</td>
<td>7° 12°</td>
<td>7° 12°</td>
</tr>
<tr>
<td>Jyeṣṭhā</td>
<td>7° 18°</td>
<td>7° 18°</td>
</tr>
<tr>
<td>Mūla</td>
<td>8° 1°</td>
<td>8° 1° 30'</td>
</tr>
<tr>
<td>Pūrvāsādha</td>
<td>8° 14°</td>
<td>8° 14° 30'</td>
</tr>
<tr>
<td>Uttarāsādha</td>
<td>8° 27°</td>
<td>8° 26° 30'</td>
</tr>
<tr>
<td>Junction-star of</td>
<td>Longitude given in</td>
<td>Difference</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td><em>Mahā-Bhāskarīya</em></td>
<td><em>Laghu-Bhāskarīya</em></td>
</tr>
<tr>
<td>Sravaṇa</td>
<td>9° 15'</td>
<td>9° 14° 30'</td>
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<tr>
<td>Dhanisṭhā</td>
<td>9° 26'</td>
<td>9° 25° 30'</td>
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<td>Śatabhiṣak</td>
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<td>10° 7'</td>
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<td>10° 28'</td>
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<td>11° 15'</td>
<td>11° 15'</td>
</tr>
<tr>
<td>Revatī</td>
<td>12°</td>
<td>12°</td>
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</table>

The following table gives the longitudes of the junction-stars of the *nakṣatras* as stated in the *Mahā-Bhāskarīya*, the *Laghu-Bhāskarīya*, the *Śīṣya-dhī-ṛṇḍhika*, the *Śūrya-siadhānta*, the *Siddhānta-śekhara*, and the *Siddhānta-śiromāṇi*:

**Longitudes of the Junction-Stars according to various Hindu Authorities**

<table>
<thead>
<tr>
<th>Junction-star of</th>
<th>Longitude according to</th>
<th>(Polar) longitude according to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>MBh</em></td>
<td><em>LBh</em></td>
</tr>
<tr>
<td>Aśvinī</td>
<td>8°</td>
<td>8°</td>
</tr>
<tr>
<td>Bharaṇī</td>
<td>27°</td>
<td>26°30'</td>
</tr>
<tr>
<td>Krṭṭikā</td>
<td>36°</td>
<td>36°</td>
</tr>
<tr>
<td>Rohiṇī</td>
<td>49°</td>
<td>50°</td>
</tr>
<tr>
<td>Mṛgaśīrā</td>
<td>62°</td>
<td>62°</td>
</tr>
<tr>
<td>Ārdrā</td>
<td>70°</td>
<td>70°</td>
</tr>
<tr>
<td>Punarvasu</td>
<td>92°</td>
<td>92°</td>
</tr>
<tr>
<td>Junction-star of</td>
<td>Longitude according to</td>
<td>(Polar) longitude according to</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
<td>MBh</td>
<td>LBh</td>
</tr>
<tr>
<td>Pugya</td>
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<td>105°</td>
</tr>
<tr>
<td>Āśleṣā</td>
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<td>114°</td>
</tr>
<tr>
<td>Maghā</td>
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<td>128°30’</td>
</tr>
<tr>
<td>Pūrva Phālgunī</td>
<td>141°</td>
<td>141°</td>
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<tr>
<td>Uttarā Phālgunī</td>
<td>154°</td>
<td>154°</td>
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<tr>
<td>Hasta</td>
<td>173°</td>
<td>173°</td>
</tr>
<tr>
<td>Citrā</td>
<td>185°</td>
<td>185°</td>
</tr>
<tr>
<td>Svāti</td>
<td>197°</td>
<td>197°</td>
</tr>
<tr>
<td>Viśākhā</td>
<td>212°</td>
<td>212°</td>
</tr>
<tr>
<td>Anurādhā</td>
<td>222°</td>
<td>222°</td>
</tr>
<tr>
<td>Jyeṣṭhā</td>
<td>228°</td>
<td>228°</td>
</tr>
<tr>
<td>Mūla</td>
<td>241°</td>
<td>241°30’</td>
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<tr>
<td>Pūrvaśādha</td>
<td>254°</td>
<td>254°30’</td>
</tr>
<tr>
<td>Uttarāśādha</td>
<td>267°</td>
<td>266°30’</td>
</tr>
<tr>
<td>Śravana</td>
<td>285°</td>
<td>284°30’</td>
</tr>
<tr>
<td>Dhanisthā</td>
<td>296°</td>
<td>295°30’</td>
</tr>
<tr>
<td>Śatabhiṣak</td>
<td>307°</td>
<td>307°</td>
</tr>
<tr>
<td>Pūrva-Bhādrapada</td>
<td>328°</td>
<td>328°</td>
</tr>
<tr>
<td>Uttara-Bhādrapada</td>
<td>345°</td>
<td>345°</td>
</tr>
<tr>
<td>Revati</td>
<td>360°</td>
<td>360°</td>
</tr>
</tbody>
</table>
The longitudes given in the Mahā-Bhāskarīya, the Laghu-Bhāskarīya, and the Śīya-dhi-vṛddhīda are the usual celestial longitudes, whereas those given in the Sūrya-siddhānta, the Brāhma-sphuṭa-siddhānta, the Siddhānta-śekhara and the Siddhānta-śiromaṇi are the polar longitudes. This explains why there are significant differences between them, but, as should be expected, the celestial longitudes as also the polar longitudes exhibit general agreement amongst themselves. The minor differences that occur in a few cases are probably due to the errors of observation or to the different methods used.

Celestial latitudes of the junction-stars, definition of the conjunction of a planet with a star, and a rule for determining the distance between a planet and a star when they are in conjunction:

66(ii)-71(i). North, ten, twelve, five; south, five, ten, eleven; north, six, zero; south, seven, zero; north, twelve, thirteen; south, seven, two; north, thirty-seven; south, one and a half, three, four, eight plus one-third, seven, seven plus one-third; north, thirty, thirty-six; south, eighteen minutes; north, twenty-four, twenty-six, zero—these have been stated by the learned to be the degrees of the celestial latitudes of the junction-stars of the nakṣatras beginning with Aśvinī.

All planets having their longitudes equal to those of the junction-stars are seen in conjunction with them.

The distance between a planet and a star (when they are in conjunction) is determined from their celestial latitudes.

The celestial latitudes of the junction-stars stated above are exhibited in the following table. We also give the celestial latitudes stated in the other important works on Hindu astronomy.

---

1 That is, the longitudes of those points where the secondaries to the equater passing through the junction-stars intersect the ecliptic.

2 See MBh, vi. 54,
### LATITUDES OF THE JUNCTION-STARS

Celestial Latitudes of the Junction-Stars according to various Hindu Authorities

<table>
<thead>
<tr>
<th>Junction-star of</th>
<th>$M^{b}h$</th>
<th>$L^{b}h$</th>
<th>$S_{i}D^{V}_{r}$</th>
<th>$S_{i}S_{i}$</th>
<th>$B_{r}.S_{p}.S_{i}$, $K_{K}$, $S_{i}S_{e}$</th>
<th>$S_{i}S_{i}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aśvinī</td>
<td>10° N</td>
<td>10° N</td>
<td>10° N</td>
<td>10° N</td>
<td>10° N</td>
<td>10° N</td>
</tr>
<tr>
<td>Bharani</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
</tr>
<tr>
<td>Kṛttikā</td>
<td>5° N</td>
<td>5° N</td>
<td>5° N</td>
<td>5° N</td>
<td>4°31' N</td>
<td>4°30' N</td>
</tr>
<tr>
<td>Rohini</td>
<td>5° S</td>
<td>5° S</td>
<td>5° S</td>
<td>5° S</td>
<td>4°33' S</td>
<td>4°30' S</td>
</tr>
<tr>
<td>Mrgaśirā</td>
<td>10° S</td>
<td>10° S</td>
<td>10° S</td>
<td>10° S</td>
<td>10° S</td>
<td>10° S</td>
</tr>
<tr>
<td>Ārdrā</td>
<td>11° S</td>
<td>11° S</td>
<td>11° S</td>
<td>9° S</td>
<td>11° S</td>
<td>11° S</td>
</tr>
<tr>
<td>Punarvasu</td>
<td>6° N</td>
<td>6° N</td>
<td>6° N</td>
<td>6° N</td>
<td>6° N</td>
<td>6° N</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Āśleṣā</td>
<td>7° S</td>
<td>7° S</td>
<td>7° S</td>
<td>7° S</td>
<td>7° S</td>
<td>7° S</td>
</tr>
<tr>
<td>Maghā</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pūrvā-Phālgunī</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
<td>12° N</td>
</tr>
<tr>
<td>Uttarā-Phālgunī</td>
<td>13° N</td>
<td>13° N</td>
<td>13° N</td>
<td>13° N</td>
<td>13° N</td>
<td>13° N</td>
</tr>
<tr>
<td>Hasta</td>
<td>7° S</td>
<td>7° S</td>
<td>8° S</td>
<td>11° S</td>
<td>11° S</td>
<td>11° S</td>
</tr>
<tr>
<td>Citrā</td>
<td>2° S</td>
<td>2° S</td>
<td>2° S</td>
<td>2° S</td>
<td>1°45' S</td>
<td>1°45' S</td>
</tr>
<tr>
<td>Svāti</td>
<td>37° N</td>
<td>37° N</td>
<td>37° N</td>
<td>37° N</td>
<td>37° N</td>
<td>37° N</td>
</tr>
<tr>
<td>Viśākhā</td>
<td>1°30' S</td>
<td>1°30' S</td>
<td>1°30' S</td>
<td>1°30' S</td>
<td>1°23' S</td>
<td>1°20' S</td>
</tr>
<tr>
<td>Anurādhā</td>
<td>3° S</td>
<td>3° S</td>
<td>3° S</td>
<td>3° S</td>
<td>1°44' S</td>
<td>1°45' S</td>
</tr>
<tr>
<td>Jyeṣṭhā</td>
<td>4° S</td>
<td>4° S</td>
<td>4° S</td>
<td>4° S</td>
<td>3°30' S</td>
<td>3°30' S</td>
</tr>
<tr>
<td>Mūla</td>
<td>8°20' S</td>
<td>8°30' S</td>
<td>8°30' S</td>
<td>9° S</td>
<td>8°30' S</td>
<td>8°30' S</td>
</tr>
<tr>
<td>Pūrvāśādha</td>
<td>7° S</td>
<td>7° S</td>
<td>5°20' S</td>
<td>5°30' S</td>
<td>5°20' S</td>
<td>5°20' S</td>
</tr>
<tr>
<td>Uttarāśādha</td>
<td>7°20' S</td>
<td>7° S</td>
<td>5° S</td>
<td>5° S</td>
<td>5° S</td>
<td>5° S</td>
</tr>
<tr>
<td>Junction-star of</td>
<td>Latitude Given in</td>
<td>(Polar) latitude give in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MBh</td>
<td>LBh</td>
<td>ŚiDVṛ</td>
<td>ŚuŚi</td>
<td>BrSpSl, KK, SiŚe</td>
<td>ŚiŚi</td>
</tr>
<tr>
<td>Śravana</td>
<td>30° N</td>
<td>30° N</td>
<td>30° N</td>
<td>30° N</td>
<td>30° N</td>
<td>30° N</td>
</tr>
<tr>
<td>Dhaniśṭhā</td>
<td>36° N</td>
<td>36° N</td>
<td>36° N</td>
<td>36° N</td>
<td>36° N</td>
<td>36° N</td>
</tr>
<tr>
<td>Śatabhiṣak</td>
<td>18° S</td>
<td>18° S</td>
<td>20° S</td>
<td>30° S</td>
<td>18° S</td>
<td>20° S</td>
</tr>
<tr>
<td>Pūrva-Bhādra-pada</td>
<td>24° N</td>
<td>24° N</td>
<td>24° N</td>
<td>24° N</td>
<td>24° N</td>
<td>24° N</td>
</tr>
<tr>
<td>Uttara-Bhādra-pada</td>
<td>26° N</td>
<td>26° N</td>
<td>26° N</td>
<td>26° N</td>
<td>26° N</td>
<td>26° N</td>
</tr>
<tr>
<td>Revaṭṭ</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Celestial latitudes of the Moon when she occults some of the prominent stars of the zodiac:

71(ii)-75(i). It is stated that the Moon, moving towards the south of the ecliptic, obliterates (i.e., occults) the cart of Rohini (i.e., the constellation of Hyades), when her latitude amounts to 60 minutes; the junction-star (of Rohini) (i.e., Aldebaran), when her latitude amounts to 256 minutes; (the junction-star of) Citrā (i.e., Spica), when her latitude amounts to 95 minutes; (the junction-star of) Jyeṣṭhā (i.e., Antares), when her latitude amounts to 200 minutes; (the junction-star of) Anurādhā\(^1\) when her latitude amounts to 150 minutes; (the junction-star of) Śatabhiṣak (i.e., λ Aquarii), when her latitude amounts to 24 minutes; (the junction-star of) Viśākhā\(^2\), when

---

\(^1\) According to H. T. Colebrooke and E. Burgess, it is δ Scorpii. According to Bentley, it is β Scorpii.

\(^2\) According to Colebrooke, it is α or λ Librae; according to Whitney and Burgess, it is 24 Librae.
her latitude amounts to 88 minutes; and (the junction-star of) Revati (i.e., ζ Piscium), when her latitude vanishes. When she moves towards the north (of the ecliptic), she occults the nakṣatra Kṛttikā (i.e., the Pleiades), when her latitude amounts to 160 minutes; and the central star of the nakṣatra Maghā, when she assumes the greatest northern latitude. These minutes (of the Moon’s latitude) which have been stated (here) in connection with the occultation of a star by the planet (Moon) are based on actual observation made by means of the instrument (called) Yaṣṭi.¹

¹ The occultations of the stars of the nakṣatras are stated also in ŚūSi, viii. 13; BrSpSi, x. 11-12; KK, x. 15-16; LBh, viii. 11-16; ŚiDVr, I, xi. 11; SiSe, xii. 8-9.
CHAPTER IV

TRUE LONGITUDE OF A PLANET

Definition of the Sun’s mean anomaly:

1. Having applied the correction for the (local) longitude to the mean longitude of the Sun, subtract (therefrom) the longitude of the Sun’s apogee (ucca): the remainder is the Sun’s (mean) anomaly. In that (anomaly), three signs form a quadrant.

That is to say,

Sun’s mean anomaly = (mean longitude of the Sun) — (longitude of the Sun’s apogee).

The Sun’s apogee is the remotest point of the Sun’s apparent orbit.

Beginning with the Sun’s apogee, in Hindu astronomy, the kakṣāvetta (deferent or concentric) for the Sun is divided into four equal parts called anomalistic quadrants (pada or pāda) and twelve equal parts called anomalistic signs (rāśi). Thus there are three anomalistic signs in an anomalistic quadrant. The anomalistic signs are given the same names as the signs of the zodiac, viz., Aries (meṣa), Taurus (vrṣa), Gemini (mithuna), etc. When the mean anomaly of the Sun is between 0° and 180°, the Sun is said to be in the six signs (or in the half-orbit) beginning with the anomalistic sign Aries;¹ and when the mean anomaly of the Sun is between 90° and 270°, the Sun is said to be in the six signs (or in the half-orbit) commencing with the anomalistic sign Cancer; and so on. The same is true also for the planets, Mars, etc.

A rule relating to the Rsine of the Sun’s mean anomaly:

2. (Of the parts of the Sun’s mean anomaly lying) in the odd quadrants, calculate the Rsine; and (of the parts lying) in the even quadrants, calculate the Rversed-sine. The method

¹ This rule occurs also in SaSi, ii. 29; BrSpSi, ii. 12(i); ŚiDVr, I, ii. 10; Śīśe, iii. 12; ŚiŚi, I, ii. 18-19(i).

² Or, that the mean anomaly is in the six signs (or in the half-orbit) beginning with the sign Aries.
for finding the Rsines (i.e., Rsines and Rversed-sines) is being
told in detail (below).

For example, if the Sun’s mean anomaly is 140°, calculate the
Rsine of 90° and the Rversed-sine of 50°; if the Sun’s mean anomaly is
240°, calculate the Rsine of 90°, the Rversed-sine of 90°, and the
Rsine of 60°; and if the Sun’s mean anomaly be 300°, calculate the Rsine
of 90°, the Rversed-sine of 90°, again the Rsine of 90°, and the Rversed-
sine of 30°.

The above passage shows that in the time of Bhāskara I one of the
methods used for finding the Rsine of an arc (>90°) was to apply the
following formulae:

\[
\begin{align*}
\text{Rsin} & (90° + \theta) = \text{Rsin} 90° - \text{Rversin} \theta. \\
\text{Rsin} (180° + \theta) & = \text{Rsin} 90° - \text{Rversin} 90° - \text{Rsin} \theta \\
& = - \text{Rsin} \theta.
\end{align*}
\]

\[
\begin{align*}
\text{Rsin} (270° + \theta) & = \text{Rsin} 90° - \text{Rversin} 90° - \text{Rsin} 90° \\
& + \text{Rversin} \theta \\
& = - \text{Rsin} 90° + \text{Rversin} \theta,
\end{align*}
\]

where \(\theta < 90°\).

A rule for finding the Rsine (or Rversed-sine) of an arc
(<90°):  

3-4(i). Reduce the arc to minutes and then divide by
225: the quotient denotes the number of (tabulated) Rsine-
differences (or Rversed-sine-differences) to be taken completely. Then multiply the remainder by the next (or current)
Rsine-difference (or Rversed-sine-difference) and divide (the
product) by 225. Add the quotient (thus obtained) to the sum
of the (tabulated) Rsine-differences (or Rversed-sine-differences)
obtained before. The sum thus obtained is the Rsine (or
Rversed-sine) of the given arc.\(^1\)

This rule gives a method for calculating the Rsine or Rversed-sine
of an arc by the help of the following table of Rsine-differences given by
Āryabhaṭa I in his Āryabhaṭīya\(^2\).

\(^1\) This rule occurs also in \(ŚuŚi\) ii. 31-32; \(BrSpŚi\), ii. 10; \(LBh\), ii. 2
(ii)-3(i); \(SiDVṛ\), I, ii. 12; \(SiŚe\), iii. 15; \(SiŚi\), I, ii. 10(ii)-11.

\(^2\) i. 12. This table has been referred to in \(MBh\), vii. 13,
### Table of Rsine-differences

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Rsine-difference in minutes</th>
<th>Serial No.</th>
<th>Rsine-difference in minutes</th>
<th>Serial No.</th>
<th>Rsine-difference in minutes</th>
<th>Serial No.</th>
<th>Rsine-difference in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>225</td>
<td>7</td>
<td>205</td>
<td>13</td>
<td>154</td>
<td>19</td>
<td>79</td>
</tr>
<tr>
<td>2</td>
<td>224</td>
<td>8</td>
<td>199</td>
<td>14</td>
<td>143</td>
<td>20</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>222</td>
<td>9</td>
<td>191</td>
<td>15</td>
<td>131</td>
<td>21</td>
<td>51</td>
</tr>
<tr>
<td>4</td>
<td>219</td>
<td>10</td>
<td>183</td>
<td>16</td>
<td>119</td>
<td>22</td>
<td>37</td>
</tr>
<tr>
<td>5</td>
<td>215</td>
<td>11</td>
<td>174</td>
<td>17</td>
<td>106</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>210</td>
<td>12</td>
<td>164</td>
<td>18</td>
<td>93</td>
<td>24</td>
<td>7</td>
</tr>
</tbody>
</table>

This table gives the Rsine-differences corresponding to the twenty-four elementary arcs in which a quadrant of a circle is divided, each elementary arc being equal to 225 minutes. The same table reversed becomes the table of Rversed-sine-differences.

### Table of Rversed-sine-differences

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Rversed-sine-difference in minutes</th>
<th>Serial No.</th>
<th>Rversed-sine-difference in minutes</th>
<th>Serial No.</th>
<th>Rversed-sine-difference in minutes</th>
<th>Serial No.</th>
<th>Rversed-sine-difference in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>7</td>
<td>93</td>
<td>13</td>
<td>164</td>
<td>19</td>
<td>210</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>8</td>
<td>106</td>
<td>14</td>
<td>174</td>
<td>20</td>
<td>215</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>9</td>
<td>119</td>
<td>15</td>
<td>183</td>
<td>21</td>
<td>219</td>
</tr>
<tr>
<td>4</td>
<td>51</td>
<td>10</td>
<td>131</td>
<td>16</td>
<td>191</td>
<td>22</td>
<td>222</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>11</td>
<td>143</td>
<td>17</td>
<td>199</td>
<td>23</td>
<td>224</td>
</tr>
<tr>
<td>6</td>
<td>79</td>
<td>12</td>
<td>154</td>
<td>18</td>
<td>205</td>
<td>24</td>
<td>225</td>
</tr>
</tbody>
</table>
The method for calculating the Rsine or Rversed-sine of an arc, as stated in the text, may be explained by means of an example as follows:

Example. Calculate Rsin 32° and Rversin 32°.

Reducing 32 degrees to minutes, we get 1920'. Dividing this by 225, we get 8 as the quotient and 120 as the remainder.

(1) The sum of the first 8 Rsine-differences is 1719'. Multiplying the remainder 120 by the 9th Rsine-difference (viz. 191') and dividing the product by 225, we get 101' 52". Adding this to the previous sum, we get 1820' 52" or 1821' approx. This is the value of Rsin 32°.

(2) The sum of the first 8 Rversed-sine-differences is 460'. Multiplying the remainder 120 by the 9th Rversed-sine-difference (viz. 119') and dividing that product by 225, we get 63' 28". Adding this to the previous sum, we get 523' 28" or 523' approx. This is the value of Rversin 32°.1

The above method for finding the Rsine of a given arc is evidently based on the simplest law of interpolation, viz. that of proportion. In later works, we come across more elegant methods of interpolation. We state here two of them.

1. Brahmagupta's formula.

If \( \theta < 225' \) and \( t \) be an integer, then

\[
\text{Rsine} \ (225' t + \theta') = \text{sum of } t \text{ Rsine-differences} \\
\quad + \frac{\theta'}{225} \left\{ \frac{t \text{th Rsine-diff.} + (t+1) \text{th Rsine-diff.}}{2} \right. \\
\quad \quad \left. - \frac{\theta'}{225} \cdot \frac{t \text{th Rsine-diff.} - (t+1) \text{th Rsine-diff.}}{2} \right\}. \quad (1)
\]

= sum of \( t \) Rsine-differences

\[
+ \frac{\theta'}{225} \cdot \{(t+1) \text{th Rsine-difference}\} \\
+ \frac{1}{2} \cdot \frac{\theta'}{225} \left( \frac{\theta'}{225} - 1 \right) \cdot \{(t+1) \text{th Rsine-difference} \\
\quad - t \text{th Rsine-difference}\}. \quad (2)
\]

1 Using modern four-figure tables and assuming that one radian = 206265", we get Rsine 32° = 30° 21' 43" approx. and Rversin 32° = 8°42' 22" approx. This shows that the values derived from Āryabhaṭa I's table give fairly good approximations to the Rsines and Rversed-sines up to minutes of arc.
Form (1) occurs in P. C. Sengupta's edition of the *Khandakhadyaka* of Brahmagupta and also in the *Siddhānta-siromāṇi* of Bhāskara II. Form (2) is found to occur in Paramesvara's commentary on the *Laghu-Bhāskarīya*. This formula agrees with Newton's interpolation formula for equidistant knots.

2. Madhava's formula.

If \( t \) be a positive integer and \( \theta < 225' \), then
\[
R \sin (225' t + \theta') = \text{sum of } t \text{ } R \text{ } \sin \text{ } \text{differences}
\]

\[
+ \frac{\theta \times [R \cos \{225' (t + 1)\} + R \cos (225't)]}{2R}
\]

This formula is ascribed to Mādhava by Nīlakanṭha in his commentary on the *Āryabhaṭīya*. It occurs also in the *Tantra-saṅgraha*.

In Chapter VII of the present work, Bhāskara I gives a very interesting method for finding the Rsine of a given arc without the use of a table.

A rule for finding the Sun's equation of the centre:

4(ii). The Rsines and Rversed-sines (of the parts of the Sun's mean anomaly lying in the odd and even quadrants respectively) should be (severally) multiplied by the (Sun's) own epicycle and divided by 80; the resulting quantities should be subtracted and added (in the manner prescribed below).

Application of the Sun's equation of the centre:

5. The resulting quantities due to the first, second, third and fourth anomalousic quadrants should always be respectively subtracted from, added to, added to, and subtracted from the Sun's mean longitude corrected for the (local) longitude.

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1 ix. 8.
2 I, ii, 16.
3 ii. 2(ii)-3(i).
4 ii. 12.
5 ii. 10-13(i).
6 See *infra* chapter VII, stanzas 17-19.
7 This correction is found also in *BrSpSi*, i. 15(ii) and *SiŠe*, iii, 27.
8 This correction is found also in *BrSpSi*, ii. 16(i). Also see *SiŠe*, iii. 28(i).
Alternative rule for the determination and application of the Sun's equation of the centre (called bāhuphala):

6. Or, (find the bāhuphala and) subtract the bāhuphala when the (Sun's mean) anomaly is in the half-orbit beginning with Aries; and add that when (the Sun's mean anomaly is) in the half-orbit beginning with Libra. This correction should always be performed by one who seeks the true longitude (of the Sun).\(^1\)

Bāhu (due to a planet's mean anomaly) is defined in stanza 8 below. It is the arcual distance of a planet from its apogee or perigee, whichever is nearer. The Sun's bāhuphala is obtained by the following formula:

\[
\text{Sun's bāhuphala} = \frac{\text{(Sun's tabulated epicycle)} \times \text{Rs} \sin (\text{bāhu due to the Sun's mean anomaly})}{80}
\]

The Sun's tabulated epicycle is 3.\(^2\)

The Sun's bāhuphala corresponds to the Sun's equation of the centre, which is shown by means of the Hindu epicyclic theory as follows:

In the adjoining figure, the bigger circle UMN, centred at the Earth E, is the Sun's mean orbit called kaksāvṛtta (deferent); the small circles are nicoccavrītas (epicycles); and U is the Sun's ucca (apogee).

Under the epicyclic theory, the mean Sun is supposed to move on the deferent, and the true Sun is supposed to move on its epicycle (centred at the mean planet) with the same angular velocity as the mean Sun, has relative to the apogee but in the opposite sense. (See the arrows).

---

\(^1\) This rule is found to occur also in ŚūSi, ii. 39; ŚiDVṛ, I, ii. 14; ŚiŚe, iii. 26(i).

\(^2\) Vide infra, vii. 16. It must be noted that the epicycles have been tabulated after abrading them by 4½.
Initially, when the mean Sun is at $U$, the true Sun is at $U_1$. Subsequently, when the mean Sun is at $M$, the true Sun is at $T_1$, such that $MT_1$ is parallel to $EU$. Since both the mean Sun and the true Sun have the same angular velocity relative to the apogee, the line $MT_1$ will always be parallel to $EU$.

According to the Hindu astronomers, the tabulated (manda) epicycles are the mean epicycles (i.e., the epicycles corresponding to the mean distances of the planets) whereas the true epicycles (on which the planets are supposed to move) are those which correspond to their true distances.\footnote{See \textit{BrSpSi}, xxi. 29; \textit{SiŚe}, xvi. 24; \textit{SiŚi}, II, v. 36-37. Also see Bhāskara II's comm. on \textit{SiŚi}, II, v. 36-37; and the extract from the \textit{Ādityapratāpa-siddhānta} quoted by Āmarāja in his comm. on \textit{KK}, page 33.} That is to say, the point $T_1$ in the above figure is not the position of the true Sun.

According to the Hindu theory the true epicycle and the true position of the Sun, when the mean Sun is at $M$, are obtained as follows:

Let $C$ be a point in $EU$ such that $EC=UU_1$. Join $CT_1$ and let it intersect the deferent at $S$. Produce $ES$ and $MT_1$ to meet at $T$. Then $MT$ is the radius of the true epicycle at $M$ and $T$ the true position of the Sun. Obviously, the epicycle varies from point to point.

If $\Upsilon$ denote the first point of Aries. Then

- Sun's mean longitude $= \text{arc } \Upsilon UM$,
- Sun's true longitude $= \text{arc } \Upsilon US$.

The difference between the two, i.e., arc $SM$, is the Sun's equation of the centre.

Let $MA$ be perpendicular to $EU$ and $T_1B_1$ and $SB$ be perpendiculars to $EM$ or $EM$ produced. $T_1B_1$ is called $bāhuphala$ or $bhujāphala$ and $B_1M$ is called $kōṭiphala$.

The triangles $B_1MT_1$ and $MAE$ are similar. Therefore,

\[
\frac{T_1B_1}{T_1M} = \frac{MA}{EM},
\]

or, $T_1B_1$, i.e., Sun's $bāhuphala = \frac{T_1M \times MA}{EM}$

\[
= \frac{(\text{radius of Sun's mean epicycle}) \times R \sin (\text{arc } MU)}{R}
\]

(Sun's tabulated epicycle) $\times R \sin (bāhu \text{ due to the Sun's mean anomaly})$.  

\[\text{Page 112} \]
SUN'S EQUATION OF THE CENTRE

But $T_1 B_1 = SB = \text{arc SM approx.}$

Hence it follows that the Sun's $bāhuphala$ is the same as the Sun's equation of the centre.

If $\theta$ denote the $bāhu$ due to the Sun's mean anomaly, then according to Āryabhaṭa I and Bhāskara I

\[
\text{Sun's } bāhuphala = \frac{3 \times R \sin \theta}{80} = \frac{3 \times 3438' \times \sin \theta}{80} = \frac{128'9 \sin \theta}{0.0375 \sin \theta \text{ radians.}} \tag{1}
\]

According to Ptolemy, the greatest equation of the centre for the Sun = $2^\circ 23'$. Therefore, according to him,

\[
\text{Sun's equation of the centre} = 2^\circ 23' \sin \theta = \frac{143' \sin \theta}{3438} \text{ radians} = \frac{0.0416 \sin \theta \text{ radians.}}{\tag{2}}
\]

According to modern astronomy,

\[
\text{Sun's equation of the centre} = 2e \sin \theta, \text{ where } e = \frac{0.0167}{\text{0.0334 } \sin \theta}, \tag{3}
\]

neglecting $e^2$ and higher powers of $e$.

Comparison of the results (1), (2), and (3) shows that the Hindu approximation for the Sun's equation of the centre is good enough and much better than that of Ptolemy.

Addition and subtraction of the $bāhuphala$.

When the Sun's mean anomaly is less than $180^\circ$, the true Sun is behind the mean Sun; and when the Sun's mean anomaly is greater than $180^\circ$, the true Sun is in advance of the mean Sun. Hence the Sun's $bāhuphala$ is subtractive or additive according as the Sun's mean anomaly is in the half-orbit beginning with Aries or in the half-orbit beginning with Libra.

The Sun's $bāhuphala$ correction is applied to the Sun's mean longitude as corrected for the longitude-correction (i.e., to the Sun's mean longitude for mean sunrise at the $svanirākṣa$ place). And after the $bāhuphala$ correction has been made, we obtain the Sun's true longitude for mean sunrise at the $svanirākṣa$ place.
Sun's correction for the equation of time due to the eccentricity of the ecliptic (called bhujāntara or bhujāvivara correction):

7. Multiply the mean daily motion (of the Sun) by the (Sun's) equation (of the centre derived from the Rsines and Rversed-sines of the parts of the Sun's mean anomaly lying in the odd and even quadrants respectively)\(^1\) or by the (Sun's) bāhupala (i.e., the Sun's equation of the centre derived from the bāhu) and then divide the product by the number of minutes in a circle (i.e., by 21600); apply that (as correction, positive or negative, to the Sun's mean longitude corrected for the local longitude and for the Sun's equation of the centre) as before.\(^2\)

The bhujāntara correction is the third correction to be applied to the Sun's mean longitude. By this correction "allowance is made for that part of the equation of time, or of the difference between mean and apparent solar time, which is due to the difference between the Sun's mean and true places".\(^3\) This correction having been applied to the Sun's longitude, we obtain the Sun's true longitude for true sunrise at the svanirakṣa place.

In the case of the Moon and other planets, according to the commentator Parameśvara\(^4\), this correction is applied to the mean longitude as corrected for the longitude-correction.

The bhujāntara correction is subtractive when the Sun's mean anomaly is less than 180° and additive when the Sun's mean anomaly is greater than 180°, because in the former case true sunrise occurs earlier than mean sunrise and in the latter case true sunrise occurs later than mean sunrise.

The correction for "the equation of time due to the obliquity of the ecliptic" occurs for the first time in the Siddhānta-śekhara of Śrīpati (c.1039

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\(^1\) Vide supra stanza 4(ii).
\(^2\) Vide stanzas 5 and 6. This rule occurs also in ŚūŚi, ii. 46; BrSpŚi, ii. 29(i); ŚIDVr, I, ii. 16.
\(^3\) E. Burgess, English Translation of the Sūrya-siddhānta, Calcutta (1935), page 87.
\(^4\) Vide his comm. on MBh, iv. 29-30.
TRUE DISTANCE OF THE SUN OR MOON

A. D.) under the name of *udayāntara-saṁskāra*. It reappears in the works of Bhāskara II (1150 A. D.) and Nīlakanṭha (1500 A. D.).

Definitions of the *bāhu* and *koṭi* (due to a planet’s mean anomaly):

8. The portions (of the mean anomalistic quadrant) traversed and to be traversed (by a planet) are called *bāhu* and *koṭi* or *koṭi* and *bāhu*, according as the mean anomalistic quadrant (occupied by the planet) is odd or even. The *bāhuphala* and *koṭiphala* are obtained as before for the determination of the hypotenuse (i.e., the distance of the planet).

A rule for the determination of the true distance in minutes of the Sun or Moon:

9-12. (When the Sun or Moon is) in the first or fourth (mean anomalistic) quadrant, add the *koṭiphala* to the radius; (when) in the remaining (quadrants), subtract that from the radius: the resulting sum or difference is the upright. The square root of the sum of the squares of that and the *bāhuphala* is called the hypotenuse. Multiply that hypotenuse (severally) by the *bāhuphala* and *koṭiphala* and divide (each product) by the radius: the results are (again) the *bāhuphala* and *koṭiphala*. From them obtain the hypotenuse (again) as before. Again multiply this hypotenuse (severally) by the initial *bāhuphala* and *koṭiphala* and divide (each product) by the radius. In this way, proceeding as above, obtain the hypotenuse again and again until two successive values of the hypotenuse agree (to minutes). (Thus is obtained the nearest approximation to the true distance in minutes of the Sun or Moon).

---

1 *SiŚe*, xi. 1,
2 *SiŚi*, i. 62-63.
3 *TS*, ii. 30.
4 This definition is found also in *SūŚi*, ii. 30; *BrSpSi*, ii. 12(ii); *ŚiDVr*, i. 10-11; *SiŚe*, iii. 13(i); *SiŚi*, i. 19.
5 Cf. *LBh*, ii. 6-7.
Fig. 12 is a reproduction of the previous figure. As in the previous figure, M is the mean Sun and T the true Sun. ET is the true distance of the Sun. The above rule relates to the determination of ET. The method used is the method of successive approximations.

In the triangle ESD, where SD is parallel to EU, we have

\[ ES = R, \]

and \( SD = T_1M \), the radius of the Sun’s mean epicycle. If the value of TM, the radius of the Sun’s true epicycle, were known, the Sun’s true distance ET could be easily derived from a comparison of the similar triangles ESD and ETM. But the value of TM is unknown and is itself dependent on that of ET. Hence the necessity of the method of successive approximations (asakṛtkarma).

![Diagram](image)

Fig. 12

With centre E and radius ET₁, draw an arc of a circle cutting ET at S₁; through S₁ draw a line S₁D₁ parallel to EU and a line S₁T₁ parallel to EM meeting MT₁ produced at T₂; and from T₂ draw a line T₂B₂ perpendicular to EM produced. Again with centre E and radius ET₂ draw an arc of a circle cutting ET at S₂; through S₂ draw a line S₂D₂ parallel to EU and a line S₂T₂ parallel to EM meeting MT₂ produced at T₃; and from T₃ draw a line T₃B₃ perpendicular to EM produced. Continue this process successively. The sequence of points S₁, S₂, S₃,...and also that of points T₁, T₂,
TRUE DISTANCE OF THE SUN OR MOON

T₂,...will converge to T. This is the basis of the method used. The details are as follows:

MT₁ is taken as the first approximation r₁ to the radius of the Sun’s true epicycle and likewise ES₁, which is equal to\(^1\)

\[ \sqrt{(R+kotiphala)^2+(bāhuphala)^2}, \]

is taken as the first approximation H₁ to the Sun’s true distance.\(^2\)

Now from the similar triangles S₁D₁E and SDE,

\[ S₁D₁ = \frac{SD \times H₁}{R} = \frac{r₁ \times H₁}{R}. \]

But MT₂ = S₁D₁. Therefore,

\[ MT₂ = \frac{r₁ \times H₁}{R}. \]  \tag{1}

Again from the similar triangles T₂B₂M and MAE, we have

\[ T₂B₂ = \frac{MA \times T₂M}{R} = \frac{MA \times r₁}{R} \times \frac{H₁}{R} = \frac{bāhuphala \times H₁}{R}. \] \tag{2}

Similarly, B₂M = \(\frac{kotiphala \times H₁}{R} \). \tag{3}

Therefore,

\[ ET₂ = \sqrt{(R+MB₂)^2+T₂B₂^2}, \]

where MB₂ and T₂B₂ are given by (3) and (2) respectively.

MT₂ is taken as the second approximation r₂ to the radius of the Sun’s true epicycle and likewise ES₂ ( = ET₂ ) is taken as the second approximation H₂ to the Sun’s true distance.

Since H₁ > R, therefore from (1)

\[ r₂ > r₁; \]

and consequently,

\[ H₂ > H₁. \]

\(^1\) For, ES₁ = ET₁; and from the right-angled triangle T₁B₁E, we have \( ET₁^2 = EB₁^2 + B₁T₁^2 = (EM+MB₁)^2 + B₁T₁^2, \)

where EM = R, MB₁ is the kotiphala and B₁T₁ is the bāhuphala.

\(^2\) In the right-angled triangle EB₁T₁, B₁T₁ is called the base, EB₁ is called the upright, and ET₁ is called the hypotenuse.
Similarly, \( MT_3, MT_4, \ldots \) are the next successive approximations \( r_3, r_4, \ldots \) to the radius of the Sun's true epicycle, and \( ET_3, ET_4, \ldots \) are the next successive approximations \( H_3, H_4, \ldots \) to the Sun's true distance. As before, it can be easily shown that

\[
\begin{align*}
  r_n &< r_{n+1} \\
  \text{and } \quad H_n &< H_{n+1}.
\end{align*}
\]

Moreover, from the method of construction \( r_1, r_2, r_3, \ldots \) are each less than \( MT \), which is the upper bound of the sequence \( \{ r_n \} \), and \( H_1, H_2, H_3, \ldots \) are each less than \( ET \), which is the upper bound of the sequence \( \{ H_n \} \).

Hence it follows that

\[
\begin{align*}
  r_1 &< r_2 < r_3 < \cdots < r_n < \cdots < MT. \\
  \text{and } \quad H_1 &< H_2 < H_3 < \cdots < H_n < \cdots < ET.
\end{align*}
\]

The sequences \( \{ r_n \} \) and \( \{ H_n \} \) are each monotonic and therefore convergent. The first converges to \( MT \), the radius of the Sun's true epicycle, and the second to \( ET \), the Sun's true distance.

It may be seen that the sequences \( \{ r_n \} \) and \( \{ H_n \} \) converge rapidly so that the third or fourth approximation will give the result correct to the minute. In actual practice, however, the process of successive approximations is carried on until two successive approximations are the same to minutes of arc. For this reason, this process is sometimes called *aviṣeṣakarma* ("the process of reducing the difference to zero").\(^1\)

The method explained above is applicable to the Sun as also to the Moon.

If in the above figure \( DM \) (which is equal to \( ST_4 \)) be assumed to be equal to \( SS_1 \), i.e., \( H_1 - R \), we shall have

\[
\begin{align*}
  ED &= R - (H_1 - R) \\
       &= 2R - H_1,
\end{align*}
\]

and likewise, from the similar triangles \( SDE \) and \( TME \), we shall get

\[
\begin{align*}
  ET &= \frac{ES \times EM}{ED} \\
       &= \frac{R^2}{2R - H_1},
\end{align*}
\]

---

\(^1\) In the above discussion, we have assumed the Sun to be in the first anomalistic quadrant as shown in the figure. When the Sun is in any other quadrant, the procedure is similar.
which is Bhāskara II's approximation for the true distance of the Sun or Moon.¹

It may be pointed out here that the method of successive approximations, which has been used for finding the true distance of the Sun or Moon in the stanzas under consideration, was used by Lalla for determining the radii of the true epicycles of the Sun and Moon.²

A rule for finding the true daily motion (called karṇabhūkti) of the Sun or Moon:

13. Always multiply the (mean) daily motion of the Sun or Moon by the radius and (then) divide (the product) by the hypotenuse (i.e., the true distance) determined by the method of successive approximations; the result is the true daily motion (of the Sun or Moon).

That is

\[
\text{Sun's true daily motion} = \frac{\text{Sun's mean daily motion} \times R}{\text{Sun's true distance in minutes}},
\]

and \[
\text{Moon's true daily motion} = \frac{\text{Moon's mean daily motion} \times R}{\text{Moon's true distance in minutes}},
\]

where \( R \) is the standard radius (=3438').³

---

¹ See Si Śi, I, v. 4.
² See ŚIDVṛ, I, ii. 44.
³ The object here is to obtain the angular velocity expressed in minutes, which will correspond also to the linear velocity in a circle of radius \( R \). Parameśvara in his comm. on LBh, ii. 8 writes that, in place of the true distance in the above formulae, certain astronomers make use of the expression

\[
R = koṭipaha = \frac{(koṭipaha)^2}{R},
\]

where — or + sign is taken according as the planet is in the half-orbit beginning with the anomalistic sign Cancer or in that beginning with the anomalistic sign Capricorn. It may be pointed out that the expression (1) is an approximate value of \( H_p \), the second approximation to the true distance.
The true daily motion determined from the above formulae is called 
kārabhūkta ("the motion derived from the hypotenuse").

A rule for finding the true daily motion (called jīvābhūkta) of 
the Sun:

14. Or, multiply the current R sine-difference by the (mean) 
daily motion (of the Sun) and divide by 225. Then multiply 
that by the (Sun's) own (tabulated) epicycle and divide by 80: 
the result thus obtained subtracted from or added to the (Sun's) 
mean daily motion (according as the Sun is in the half-orbit 
beginning with the anomalistic sign Capricorn or in that begin-
ning with the anomalistic sign Cancer) gives the true daily mo-
tion (of the Sun).¹

Let $M$ and $M'$ be the mean longitudes and $S$ and $S'$ the true longi-
tudes of the Sun at sunrise yesterday and today respectively. Also let $\theta$ 
and $\theta'$ be the corresponding values of the bāhu (due to the Sun's mean 
anomaly).² Then, we have

$$S = M \mp \frac{R \sin \theta \times r_1}{80}$$

and $$S' = M' \mp \frac{R \sin \theta' \times r_1}{80},$$

where $r_1$ is the Sun's tabulated epicycle, $-\text{or} +$ sign being taken accord-
ing as the Sun's mean anomaly is less than $180^\circ$ or greater.

Therefore,

$$S' - S = (M' - M) = \frac{(R \sin \theta' - R \sin \theta) \times r_1}{80}$$

$$= m = \frac{(R \sin \theta' - R \sin \theta) \times r_1}{80},$$

where $m$ denotes the Sun's mean daily motion, $-\text{or} +$ sign being taken 
according as the Sun's mean anomaly is in the half-orbit beginning with 
the sign Capricorn or in that beginning with Cancer.

¹ This rule occurs also in Śīdra, I, ii. 38 and Siśe, iii. 40-41.
² Vide supra, stanza 8.
TRUE DAILY MOTION OF THE MOON

Neglecting the motion of the Sun’s apogee and assuming that the Rsines vary uniformly,¹ we have

\[ \text{Rsine } \theta' \leftarrow \text{Rsine } \theta = \frac{(\text{current Rsine-difference}) \times m}{225} \text{ approx.} \]

Therefore,

\[ S' - S = \frac{(\text{current Rsine-difference}) \times m \times r_i}{225 \times 80} \text{ approx.} \]

Hence the above rule.

Since the Sun’s true daily motion has been obtained here with the help of the Rsines (jīvā), therefore it is generally called jīvabhukti.

A rule for finding the true daily motion (called jīvabhukti) of the Moon:

15-17. (When the Moon is in the odd quadrant) subtract the part of the bāhu due to her mean anomaly lying in the elementary arc corresponding to the current Rsine-difference (antya-jīvādhanus-khaṇḍa) from the daily motion of the (Moon’s) mean anomaly; (when the Moon is) in the even quadrant, subtract the remainder obtained by subtracting that (part) from 225. Then take (as many) Rsine-differences in the reverse order, (if the Moon is) in the odd quadrant, or in the serial order, if the Moon is in the even quadrant, as correspond to (the above residue of) the motion of the (Moon’s) mean anomaly (literally, the mean daily motion of the moon diminished by that of its apogee). (To the sum of those Rsine-differences) add the Rsine-differences (phala) corresponding to the arcs (of the daily motion of the Moon’s mean anomaly which lie) in the first and last elementary arcs which are to be determined by proportion with the Rsine-differences (corresponding to those elementary arcs). Then calculate the (Moon’s) equation of the centre (phala) corresponding to that (i.e., multiply that by the Moon’s tabulated epicycle and divide by 80). The (Moon’s) mean daily motion, when diminished or increased by that equation (according as the

¹ The assumption that the Rsines vary uniformly is false.
Moon is in the half-orbit beginning with the anomalistic sign Capricorn or in that beginning with the anomalistic sign Cancer), becomes truer than the true.

The rationale of this rule is exactly similar to that of the previous rule. The difference is that the motion of the Moon’s apogee is also taken into account in this case.

For a criticism of the jīvābhukti, see LBh, ii. 14-15(i).

Another rule for finding the motion of the Sun or Moon for the day elapsed or for the day to elapse:

18. The difference between the longitudes (of the Sun or Moon) computed for (sunrise) today and for (sunrise) yesterday is the motion (of the Sun or Moon) which has taken place (on the day elapsed).¹ The difference between the longitudes (of the Sun or Moon) computed for (sunrise) tomorrow and for (sunrise) today is stated to be the motion (of the Sun or Moon) which will take place (today).

A rule for determining the true distance in minutes of the Sun or Moon on the basis of the eccentric (pratimandala) theory:

19-20. Subtract (the Rsine of) the greatest equation of the centre from or add that to (the Rsine of) the kotī (due to mean anomaly) depending on the anomalistic quadrant (i.e., according as the Sun or Moon is in the second and third or first and fourth anomalistic quadrants). The square root of the sum of the squares of that and (the Rsine of) the bāhu (due to mean anomaly) is the hypotenuse.² By that hypotenuse multiply (the Rsine of) the greatest equation of the centre, and then divide (the product) by the radius: add this result to or subtract that from the previous (Rsine of the) kotī (as before). Continue this process until two successive approximations for the hypotenuse are the same (up to minutes). (Thus is obtained the true distance of the Sun or Moon).

¹ This rule occurs also in SiŚi, I, ii. 36(ii).
TRUE DISTANCE OF THE SUN OR MOON

The author takes up now the Hindu eccentric theory. Here the mean Sun (or Moon) is supposed to move on a circle centred at the earth called the concentric (kakśāvṛtta), whereas the true Sun (or Moon) is supposed to move on another equal circle called the eccentric (praiimaṇḍala) with the same angular velocity as the mean Sun (or Moon) has. The centre of the eccentric is supposed to be deviated from the Earth towards the Sun’s (or Moon’s) apogee by an amount equal to the Rsine of the Sun’s (or Moon’s) greatest equation of the centre.

In Fig. 13, the circle UMNY centred at E, the Earth, is the concentric and the circle $U_1T_1L$ centred at C is the eccentric for the Sun. When the mean Sun is at U, the true Sun is at $U_1$(the apogee). Subsequently, when the mean Sun is at M, the true Sun is at $T_1$. Since the mean Sun and the true Sun have the same angular velocity relative to the apogee, the line $MT_1$ will always be parallel to the apse line EU.

Let XY be perpendicular to EU through E, and $T_1B$ perpendicular to XY. Then in the triangle $T_1BE$, right-angled at B, we have

$$BE = MA = R\sin (\text{arc } MU),$$

and $T_1B = T_1M + MB = EC + R\sin (\text{arc } MX)$,

where the arc MX is the kofti and EC is the Rsine of the greatest equation of the centre for the Sun.

Had the length EC been equal to the radius of the Sun’s true epicycle for the mean sun at $MT_1E$ would have been the Sun’s true distance, but EC corresponds to the radius of the Sun’s tabulated epicycle, which is mean and not true, therefore $T_1$ is not the true position of the Sun and likewise $T_1E$ is not the true distance of the Sun. The true distance is determined as follows:

Join $T_1C$ and let it intersect the concentric at S. Produce $MT_1$ and ES to meet at T. Then MT denotes the true distance between the centres of the concentric and the eccentric, T the position of the true Sun, and ET the true distance of the sun.
The method stated in the text relates to the determination of ET. It is based on the process of successive approximations and may be explained as follows:

With centre E and radius ET₁ draw an arc of a circle cutting ET at the point S₁, and through S₁ draw a line parallel to EM meeting MT at T₂. Again with centre E and radius ET₂ draw an arc of a circle cutting ET at S₂, and through S₂ draw a line parallel to EM to meet MT at T₃. Continue this process repeatedly. Also let SD₁, S₁D₂, S₂D₃,... be parallel to EU.

The method begins with assuming MT₁ as the first approximation r₁ to MT and likewise ET₁ is taken as the first approximation H₁ to ET.

Now from the similar triangles S₁D₁E and SDE, we have

\[ S₁D₁ = \frac{SD \times ES₁}{R} = \frac{r₁ \times H₁}{R} \]

But \( S₁D₁ = MT₂ \).

Therefore, \( MT₂ = \frac{r₁ \times H₁}{R} \). (1)

Therefore, from the triangle T₂BE, right-angled at B, we have

\[ ET₂ = \sqrt{(MB + MT₂)^2 + BE^2} \]

where \( MT₂ \) is given by (1),

\( MT₂ \) is taken as the second approximation r₂ to MT, and ET₂ as the second approximation H₂ to ET.

Since \( H₁ > R \), therefore \( r₂ > r₁ \); and consequently, \( H₂ > H₁ \).

Similarly, MT₃, MT₄, ... are the next successive approximations r₃, r₄, ... to MT, and ET₃, ET₄, ... are the next successive approximations H₃, H₄, ... to ET. Obviously,

\[ rₙ < r_{ₙ+₁} \quad \text{and} \quad Hₙ < H_{ₙ+₁} \]

Moreover, from the construction it is clear that r₁, r₂, r₃, ... are each less than MT, which is the upper bound of the sequence \( \{ rₙ \} \); and H₁, H₂, H₃, ... are each less than ET, which is the upper bound of the sequence \( \{ Hₙ \} \).

Hence it follows that

\[ r₁ < r₂ < r₃ < ... < rₙ < ... < MT \]

and \( H₁ < H₂ < H₃ < ... < Hₙ < ... < ET \).
Obviously, the sequences \( \{ r_n \} \) and \( \{ H_n \} \) are convergent. The former converges to MT and the latter to ET.

It will be noticed that the convergence is rapid, so that the third or fourth approximation will give the required distance correct to the minute. In practice, the process is repeated until two successive approximations agree to minutes.\(^1\)

The process of finding the true distance of the Moon is similar.

It may be added that the position and distance of the Sun or Moon derived from the eccentric theory are the same as derived from the epicyclic theory.

A rule for the determination of the Sun's true longitude (for mean sunrise at the svarnaśā place) under the eccentric theory:

21-23. Multiply the radius by the Rsine of the bhujā (due to the Sun's mean anomaly) and divide (the product) by the (Sun's true) distance. Add the arc corresponding to that result to the longitude of the (Sun's) own apogee depending on the anomalistic quadrant (occupied by the Sun) (as follows):

(When the Sun is in the first anomalistic quadrant, add) that arc itself, (when the Sun is in the second anomalistic quadrant, add) half a circle (i.e., 180°) as diminished by that arc, (when the Sun is in the third anomalistic quadrant, add) half a circle as increased by that arc, and (when the Sun is in the fourth anomalistic quadrant, add) a circle as diminished by that arc: the result is the true longitude of the Sun (for mean sunrise at the place where the local meridian intersects the equator).\(^2\)

This is stated to be the determination (of the Sun's true longitude) under the eccentric theory. The greatest equation

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1 In the above discussion we have assumed that the Sun is in the first anomalistic quadrant as shown in the figure. When the Sun is in the other quadrants, the process is similar.

2 This rule occurs also in BrSpSi, xiv. 17-18 and SiŚe, iii. 52.
of the centre for each individual planet determines its own eccentric \((pratim\tilde{a}nda)\).

In Fig. 13, SK and TW are perpendiculArs to the apse line EU. TW (which is equal to MA) is the Rsine of the \(bhuja\) (or \(b\tilde{a}hu\)) MU, and SK is the Rsine of the true \(bhuja\) (called \(spa\tilde{a}ta-bhuja\)) SU.

Comparing the similar triangles SKE and TWE, we have

\[
\frac{SK}{SE} = \frac{TW}{TE},
\]

giving \(SK = \frac{TW \times SE}{TE}\).

or \(R\sin (arc\ SU) = \frac{R\sin (bhuja) \times R}{Sun's\ true\ distance}\).

Therefore,

\[
arc\ SU = R\sin^{-1} \left( \frac{R\sin (bhuja) \times R}{Sun's\ true\ distance} \right).
\]

(1)

Now let \(\Upsilon\) be the first point of Aries. (See Fig. 13). Then, if the Sun is in the first anomalistic quadrant (as in the figure),

Sun’s true longitude = \(arc\ U = \arc\Upsilon U + arc\ SU\).

= longitude of the Sun’s apogee + arc SU.

When the Sun (i.e., the true Sun) is in the second quadrant, say at Q, the expression on the right hand side of (1) turns out to be the value of arc QN. Hence, in this case,

Sun’s true longitude = \(arc\Upsilon Q = \arc\Upsilon U + (180^\circ - arc\ QN)\).

Similarly, in the remaining quadrants.

The method for finding the Moon’s true longitude is similar.

A rule for finding the Sun’s \(bhuj\tilde{a}ntara\) correction under the eccentric theory:

24. The (mean) daily motion (of the Sun) multiplied by the difference between the (Sun’s) true and mean longitudes computed for the local place\(^1\) and (the product then) divided by the number of minutes in a circle (i.e., by 21600) gives, as before, the (Sun’s) \(bhuj\tilde{a}ntara\).\(^2\)

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\(^1\) What is meant here is the \(svanirak\tilde{a}\) place, i.e., the place where the local meridian intersects the equator.

\(^2\) This rule occurs also in \(BrSpSi\), xiv. 19.
The bhujaṇṭara correction is, as stated before, the correction for the equation of time due to the eccentricity of the ecliptic.

An approximate formula for finding the Rsine of the Sun’s declination:

25. The Rsine of the Sun’s longitude corrected for the three corrections (viz. desāntara, bāhuphala, and bhujaṇṭara), as multiplied by 13 and divided by 32, is (the Rsine of) the Sun’s declination. The remaining determinations (such as the calculation of the day-radius, etc.) should be made as before.

From iii. 6-7, we have

\[ \text{Rsine } \delta = \frac{1397 \times \text{Rsine } \lambda}{3438}, \quad (1) \]

where \( \lambda \) and \( \delta \) are the Sun’s sāyana longitude and declination respectively.

Now

\[ \frac{1397}{3438} = \frac{1}{2} + \frac{1}{2} + \frac{1}{5} + \frac{1}{9} + \frac{1}{9}, \]

giving \( \frac{1}{2}, \frac{2}{5}, \frac{11}{27}, \frac{13}{32} \), as the successive approximations of \( \frac{1397}{3438} \).

Writing for \( \frac{1397}{3438} \) its fourth approximation \( \frac{13}{32} \), (1) reduces to

\[ \text{Rsine } \delta = \frac{13 \times \text{Rsine } \lambda}{32}, \]

which is the formula stated in the text.

A rule relating to the determination and application of the correction due to the ascensional difference of the Sun (called cara-samśkāra or cara correction):

26-27. The (mean) daily motion (of the Sun) multiplied by the asus of the (Sun’s) ascensional difference and divided by the number of asus in a day and night (i.e., by 21600) should be subtracted from or added to the (Sun’s) longitude computed for sunrise or sunset respectively, provided that the Sun is in the
northern hemisphere; if the Sun is in the southern hemisphere, it should be applied reversely.¹

In the case of other planets, this correction is determined by proportion (with the Sun’s ascensional difference and the planet’s mean daily motion); the law for its addition or subtraction (to the planet’s true longitude) is the same as in the case of the Sun.

The correction due to the Sun’s ascensional difference is the fourth and last correction to be applied to the Sun. By this correction allowance is made for the difference between the times of sunrise (or sunset) at the local and the svanirakṣa places. This is applied to the Sun’s true longitude for true sunrise at the svanirakṣa place to get the Sun’s true longitude for true sunrise at the local place.

When the Sun is in the northern hemisphere, sunrise at the local place² occurs earlier than that at the svanirakṣa place, and sunset at the local place occurs later than that at the svanirakṣa place. When the Sun is in the southern hemisphere, it is just the contrary. Hence the law of correction stated in the text.

The general formula for the cara correction is³

\[
\text{cara correction} = \frac{(\text{Sun’s asc. diff. in asus}) \times (\text{planet’s mean daily motion})}{21600}
\]

A rule for finding the semi-durations of the day and night:

28. (When the Sun is) in the northern hemisphere, one-fourth of the total duration of the day and night increased by the (Sun’s) ascensional difference, and (when the Sun is) in the southern hemisphere, one-fourth of the total duration of the day and night diminished by the (Sun’s) ascensional difference is

¹ This rule occurs also in KK (Sengupta’s edition), i. 22; ŚiDVṛ, I, ii. 19; ŚiŚī, I, ii. 53; etc.

² The local place has been always assumed to be in the northern hemisphere, i.e., to the north of the equator.

³ ŚiŚe, iii. 69.
the measure of half the day. The measure of half the night is obtained contrarily.¹

This can be easily seen to be true from the celestial sphere.

Rules relating to the corrections for the Moon:

29-30. Multiply the (Moon’s) mean daily motion by the Sun’s equation of the centre and then divide (the product) by the number of minutes in a circle (i.e., by 21600): (the result is the bhujāntara correction for the Moon). Add it to or subtract it from the Moon’s (mean) longitude (corrected for the longitude of the local place) in the same way as in the case of the Sun.

All remaining corrections for the Moon are prescribed as in the case of the Sun.

(The bhujāntara correction) for the remaining planets also is calculated from the Sun’s equation of the centre.

The general formula for the bhujāntara correction is:

\[ \text{bhujāntara correction} = \frac{\text{(Sun’s equation of the centre) \times (planet’s mean daily motion)}}{21600} \]

The formula for the bhujāntara correction for the Moon, stated in the text, is a particular case of this.

We have seen above that in the case of the Sun four corrections are applied in the following order:

(1) the longitude correction,
(2) the bhujāphala correction (i.e., the equation of the centre),
(3) the bhujāntara correction (i.e., the correction due to the Sun’s equation of the centre).
(4) the correction due to the Sun’s ascensional difference.

In the case of the Moon, the same four corrections are applied in

¹ This rule is found also in ŚūSi, i. 62-63; BrSpSi, ii. 60; KK (Sengupta’s edition), i. 23; ŚīDVṛ, I, ii. 20-21; ŚīSe, iii. 70; SiŚt, I, ii. 52.
the following order:

1. the longitude correction.

2. the bhujāntara correction (i.e., the correction due to the Sun's equation of the centre).

3. the bhujāphala correction (i.e., the Moon's equation of the centre).

4. the correction due to the Sun's ascensional difference.

In later works, two more corrections are prescribed for the Moon. The one is equivalent to (i) the deficit of the equation of the centre of the Moon plus (ii) the evjection, and the other two are what is now called “the variation”. The former occurs for the first time in the Vāteśvara-siddhānta of Vāteśvara (904 A.D.) and the Laghu-mānasas of Mañjula (932 A.D.) and the latter in the Bijopanaya of Bhāskara II (1150 A.D.).

The next six stanzas relate to the calculation of tithi, karaṇa, and nakṣatra, which are three out of the five principal elements of the Hindu Calendar, the other two being yoga and vāra (week-day), and to the phenomena of vyatipāta. The calculations for tithi, karaṇa and nakṣatra are made for sunrise.

Calculation of the tithi:

31-32. Divide the true longitude of the Moon as diminished by that of the Sun by 720 minutes (of arc); the quotient (obtained) denotes the number of tithis (elapsed). Multiply the remainder by 60 and divide (the product) by the difference between the (true) daily motions of the Sun and the Moon: then are obtained the ghaṭīs, vighaṭīs, and asus (elapsed of the current tithi). (The time in ghaṭīs, vighaṭīs, etc. of) the current tithi to elapse or elapsed is measured from sunrise.¹

A lunar (or synodic) month is defined in Hindu astronomy from one new moon to the next. There are thirty tithis (lunar days) in a lunar month. The first tithi begins at new moon (when the Sun and the Moon have the same longitude) and continues till the Moon, due to her rapid motion, is 12° (or 720') in advance of the Sun; the second tithi then begins and continues till the Moon is 24° in advance of the Sun; the third tithi


² This rule occurs also in ŚuŚi, ii. 66; BrSpŚi, ii. 62; KK (Sengupta's edition), i. 25; ŚiDVṛ, I, ii. 22; ŚiŚe, iii. 71; SiŚi, I, ii. 66.
then begins and continues till the Moon is 36° in advance of the Sun; and so on.

A lunar month is divided also into two halves, the light half and the dark half. The light half begins at new moon and continues till full moon, and the dark half begins at full moon and continues till new moon. Evidently there are fifteen *tithis* in each half. The *tithis* falling in the two halves are numbered 1, 2, 3, ...

The text gives the method for finding the number of *tithis* elapsed since new moon, and the time elapsed at sunrise since the beginning of the current *tithi*.

Calculation of the *karaṇa*:

33. The *karaṇas* (elapsed) are obtained by taking “half the measure of a *tithi* (i.e., 360 minutes)” for the diviser, and are counted with Bava. But the number of *karaṇas* elapsed in the light half of the month should be diminished by one, whereas those elapsed in the dark half of the month should be increased by one. This is what has been stated.¹

The *karaṇa* is half a *tithi*, so that there are 60 *karaṇas* in a lunar month. These *karaṇas* are divided into 8 cycles of 7 movable *karaṇas*, bearing the names Bava, Bālava, Kaulava, Taitila, Gara, Vaṇija, and Viṣṭi respectively, and 4 immovable *karaṇas*, bearing the names Śakuni, Catuspada, Nāga, and Khastugraha respectively.

¹ That is to say: If it is the light half of the month, divide the true longitude of the Moon as diminished by that of the Sun, reduced to minutes, by 360. The quotient diminished by one should be divided by seven and the remainder obtained should be counted with Bava. This gives the *karaṇa* elapsed before sunrise.

If it is the dark half of the month, subtract the longitude of the Sun from that of the Moon, and diminish that difference by six signs. Reduce it to minutes and divide by 360. The quotient increased by one should be divided by seven and the remainder obtained should be counted with Bava. This gives the *karaṇa* elapsed before sunrise.

The time elapsed at sunrise since the beginning of the current *karaṇa* should be determined from the remainder obtained in the division by 360, as in the case of the *tithi*.

This rule is found to occur also in *KK* (Sengupta’s edition), i. 27; *ŚiDVṛt, I*, ii. 24; *ŚiSe, iii.* 77; *ŚiŚi, I*, ii. 66.
The first round of the movable karaṇas begins with the second half of the first tiṣṭha in the light half of the month, and the eighth round ends on the first half of the fourteenth tiṣṭha in the dark half of the month. Thus in the light half of the month, the second karaṇa is Bālava, the third karaṇa is Bālava, the fourth karaṇa is Kaulava, and so on; and in the dark half of the month, the first karaṇa is Bālava, the second karaṇa is Kaulava, and so on.

The four immovable karaṇas occur in succession after the eighth round of the cycle of the seven movable karaṇas.

Calculation of the nakṣatras:

34. The true longitude of a planet reduced to minutes and then divided by 800 gives the number of nakṣatras passed over (by the planet). From the remainder (multiplied by 60 and) divided by the (planet’s true daily) motion are obtained the ghatis elapsed (since the planet’s entrance into the current nakṣatra).¹

We have seen that in Hindu astronomy the stars lying near the ecliptic are divided into 27 groups called nakṣatras.² Beginning with the first point of the nakṣatra Aśvini,³ the ecliptic is divided into 27 equal parts, each of 800 minutes (of arc). These divisions of the ecliptic also are called nakṣatras and given the same names as the twenty-seven star-groups, i.e., Aśvini, etc. The nakṣatras referred to in the above stanza are these divisions of the ecliptic.

Given the longitude of a planet the above rule enables us to determine the number of nakṣatras passed over by the planet and the time elapsed since it crossed into the current nakṣatra.

The phenomena of vyatīpāta:

35-36. When the sum of the (true) longitudes of the Sun and the Moon amounts to half a circle (i.e., 180°), the pheno-

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¹ This rule is found also in Sū Śi, ii. 64; BrSpSī, ii. 61; KK (Sengupta’s edition), i. 24; ŚīDVṛ, I, ii. 23(i); ŚīSē, iii. 75; ŚīŚi, I, ii. 67.
² Vide supra, Chapter III, stanzas 62-75(i).
³ The first point of the nakṣatra Aśvini (also called the first point of Aries) is the fixed point from which the longitudes of the planets are measured in Hindu astronomy. This point coincides with the junction-star of the nakṣatra Revaṭi, i.e. with ζ Piscium.
menon is called (lāta) vyatīpāta; when that (sum) amounts to a circle (i.e., 360°), the phenomenon in called vaidhrīa (vyatīpāta); and when that (sum) extends to the end of the nakṣatra Anurādhā (i.e., when that sum amounts to 7 signs, 16 degrees, and 40 minutes), the phenomenon is called sārpamastaka (vyatīpāta).

The (lāta) vyatīpāta occurs when the Sun and Moon are in different courses of motion (ayana)¹ and their (true) declinations are equal. Its region is half a circle, but due to the Moon’s latitude it may be more or less.²

The sārpamastaka vyatīpāta corresponds to the yoga known by the name vyatīpāta.

That the region of the (lāta) vyatīpāta is half a circle means that the (lāta) vyatīpāta takes place when the Sun and Moon are within half a circle measured from the first point of nakṣatra Aśvini.

The phenomena of vyatīpāta (usually called pāta or mahāpāta) are treated in detail in later works. In the Sūrya-siddhānta, Brāhma-sphuta-siddhānta, Siddhānta-śekhara, and Siddhānta-śiromaṇi, etc., a whole chapter is devoted to that subject.

In modern Hindu Calendars (called Pañcāṅga) are given the tithi, karana, Moon’s nakṣatra, and yoga current at sunrise for every day of the year and also the times when they end and the next ones begin. The yoga has not been treated by Bhāskara I, but it forms one of the five important elements of the Hindu Calendar. Like the nakṣatras, the number of these yogas is also twenty-seven. The method of finding the yoga passed over and the time elapsed at sunrise since the commencement of the current yoga is similar to that prescribed for the nakṣatra. The difference is that in the case of the yoga calculation is made with the sum of the longitudes of the Sun and the Moon, whereas in the case of the nakṣatra calculation is made with the help of the longitude of the Moon only. The first yoga (called Viṣkambha) begins when the sum of the longitudes of the Sun and moon is zero, the second yoga (called Prīti) begins when

¹ That is to say, when one has northward motion and the other has southward motion.
² For details, see SiŚi, I, xii.
that sum amounts to 13°20’, the third yoga (called Āyusmān) begins when that sum amounts to 26°40’, and so on.¹

The remaining chapter relates to the planets, Mars, Mercury, Jupiter, Venus, and Saturn.

Calculations relating to the planets, Mars, etc.:

37. (In the case of the planets, Mars, etc.) the determination of the direct and inverse Rsines (relating to the kendra, i.e., mandakendra and śīghrakendra) as also the calculation of the bhujā and koti etc. is to be made as in the case of the Sun. The differences (in the case of Mars, etc.) will now be stated.

The mandakendra and the śīghrakendra are defined by the following equations:

\[
\text{mandakendra} = \text{longitude of the mean planet} - \text{longitude of the planet’s mandocca (apogee)}.
\]

\[
\text{śīghrakendra} = \text{longitude of the planet’s śīghrocca—longitude of the true-mean planet.²}
\]

A rule for finding the (planet’s) corrected epicycle:

38-39(i). Multiply the Rsine or Rversed-sine (of the part of the kendra lying in the current quadrant³), according as the (current) quadrant is odd or even, by the difference between


There is another system of twenty-eight yogas, beginning with Ānanda. In some Hindu calendars yogas of this system are also given for each day of the month. But these yogas are only of astrological interest.

² See infra, chapter vii, stanza 12.

³ The kendra is said to be in the first quadrant if it is less than 90°, in the second quadrant if it is between 90° and 180°, and so on.
the (planet's) own epicycles (for the beginnings of the odd and even quadrants) and then divide (the product) by the radius; and apply the result (thus obtained) to the (planet's) epicycle (for the beginning of the current quadrant). Subtract (that result), when the epicycle for (the beginning of) the current quadrant is greater; add (that result), when the epicycle for (the beginning of) the current quadrant is smaller. Thus is obtained the (planet's) corrected epicycle.¹

In the case of the Sun and the Moon, which move around the Earth, we have seen that only one epicycle is contemplated which is meant to account for the eccentricity of the orbit. In the case of the planets, Mars, Mercury, Jupiter, Venus, and Saturn, which revolve round the Sun, two kinds of epicycles are envisaged, (i) manda, and (ii) śighra. We shall presently see how these epicycles are utilized to explain the motion of the planets.

Unlike the mean epicycle for the Sun or Moon, the manda and śighra epicycles for Mars, etc., are supposed to vary from place to place. Their values at the beginnings of the odd and even quadrants are given in the seventh chapter.² Those for any other point of the orbit are determined by the method taught in the stanza under consideration.

Let $\alpha$ and $\beta$ be the epicycles (manda or śighra) of a planet for the beginnings of the odd and even quadrants respectively. Then (1) if the planet be in the first quadrant (of the kendra), say at $P$, and its kendra be $\theta$,

$$\text{epicycle at } P = \alpha + \frac{(\beta - \alpha) \times R \sin \theta}{R} \quad \text{(when } \alpha < \beta)$$

$$= \alpha - \frac{(\alpha - \beta) \times R \sin \theta}{R} \quad \text{(when } \alpha > \beta)$$

and (2) if the planet be in the second quadrant (of the kendra), say at $Q$, and its kendra be $90^\circ + \phi$,

¹ This rule occurs also in ŚūSi, ii. 38 and ŚiSe, iii. 22.
² Stanzas 13-16.
epicycle at \( Q = \beta - \frac{(\beta - \alpha) \times R \text{versin} \phi}{R} \), (when \( \alpha < \beta \)).

\[ = \beta + \frac{(\alpha - \beta) \times R \text{versin} \phi}{R} \), (when \( \alpha > \beta \)).\]

Similarly, in the third and fourth quadrants.

Rule for finding the \textit{kendraphala} (i.e., \textit{mandakendra-phala} or \textit{\r{S}ighrakendra-phala}):

39(ii). By that (corrected epicycle) multiply the \( R \text{sine} \) of
the \textit{kendra} of the desired planet and then divide (the product
obtained) by 80; this is known as the (\textit{kendra}) \textit{phala}.

That is,

\[ \text{mandakendraphala} = \frac{(\text{corrected manda epicycle}) \times R \text{sin} (\text{mandakendra})}{80} \]

and \textit{\r{S}ighrakendraphala}

\[ = \frac{(\text{corrected \r{S}ighra epicycle}) \times R \text{sin} (\text{\r{S}ighrakendra})}{80} \]

By the \textit{mandakendraphala} is meant the \textit{\b{A}huphala} derived from the
planet's corrected \textit{manda} epicycle, and by the \textit{\r{S}ighrakendraphala} is
meant the \textit{\b{A}huphala} derived from the planet's corrected \textit{\r{S}ighra} epicycle.
The method of finding the \textit{\b{A}huphala} is the same as taught in the case of
the Sun.

In what follows we shall see how the \textit{mandakendraphala} and the
\textit{\r{S}ighrakendraphala} are used in finding the true geocentric
longitudes of the planets. Their significance will also then become clear.

Procedure to be adopted for finding the true geocentric longitude
in the case of Mars, Jupiter, Saturn, Mercury and Venus:

40-44. Calculate half the arc corresponding to the \textit{\text{\textit{(planet's) mandakendraphala}}}
and apply that to the \textit{(planet's) mean longitude depending on the quadrant \textit{(of the planet's kendra)} as in the case of the Sun.}
(Then calculate the $\tilde{s}igh rakendra pala$). Multiply the radius by the $\tilde{s}igh rakendra pala$ and divide (the product) by the (planet's) $\tilde{s}igh rakarna$; then reduce that to arc. Apply half of that arc to the longitude obtained above, reversely (i.e., add when the $\tilde{s}igh rakendra$ is in the half orbit beginning with the sign Aries and subtract when the $\tilde{s}igh rakendra$ is in the half orbit beginning with Libra).

Therefrom calculate (the arc corresponding to) the manda-kendra pala and apply the whole of that to the mean longitude of the planet. Thus are obtained the true-mean longitudes of Mars, Saturn, and Jupiter.

The true-mean longitude corrected for the arc derived from the $\tilde{s}igh rakendra pala$¹ (literally, the arc corresponding to the result derived from the longitude of the $\tilde{s}igh roc ca$ minus the true-mean longitude of the planet) is to be known as the true longitude. The method (to be used) for the remaining planets (i.e., Mercury and Venus) is now being told.

The longitude of the (planet's) mandoocca (i.e., apogee) reversely increased or decreased by half the arc derived from the $\tilde{s}igh rakendra pala$ determines the true-mean longitude (of the planet). And that (true-mean longitude) corrected for the arc derived from the $\tilde{s}igh ra (kendra pala)$ is known as the true longitude.²

¹ The arc derived from the $\tilde{s}igh rakendra pala$ is obtained by first multiplying the radius by the $\tilde{s}igh rakendra pala$ and dividing by the $\tilde{s}igh rakarna$ and then reducing that to arc. See stanza 41.

² The rule given in stanzas 40-43 is found also in $\tilde{A}$, iii. 23; $LBh$, ii. 32-35; $SiDVr$, I, ii. 30-34; $TS$, ii. 55-65, 66(i).
We explain below the motion of the planets, Mars, Mercury, Jupiter, Venus, and Saturn, according to the Hindu epicyclic theory.

Consider Fig. 14. E is the Earth. The bigger circle USM centred at E is the deferent (kakṣāvattra). The point U on the deferent is the planet’s mandocca (apogee). M is the position of the mean planet which is supposed to move on the deferent with mean velocity from west to east (in the anticlockwise direction indicated by an arrow). The small circle centred at M is the planet’s manda epicycle corresponding to the position M of the mean planet; this manda epicycle is determined as taught in stanzas 38-39(i). EC is equal to MM, M and C are joined by a line which intersects the deferent at the point S. MM, MM, and ES are produced to meet at the point T. This point T is, according to the Hindu astronomers, the position of the true-mean planet. The so-called true-mean planet is assumed to move on the periphery of the true epicycle of radius MT centred at M with the same velocity as the mean planet has relative to the apogee but in the opposite sense (i.e., clockwise). The point S denotes the position of the true-mean planet on the deferent.

The method prescribed here for finding the true longitudes of Mercury and Venus has been prescribed for all the planets in the Kāraṇa-prakāśa (ii (b). 3, 4), the Graha-lāghava (iii. 10), the Ravi-siddhānta- mañjarī (ii. 1), and the Kāraṇa-kaustubha (iii. 19), etc., all of them being calendrical works.
If $\Upsilon$ be the first point of Aries, then $\angle ME\Upsilon$ (or arc $MU\Upsilon$) is the mean longitude of the planet, and $\angle SE\Upsilon$ (or arc $SU\Upsilon$) is the true-mean longitude of the planet. The arc $MS$ by which the true-mean longitude of the planet differs from the mean longitude of the planet is obtained as follows:

Let $MA$ be the perpendicular from $M$ on $EU$, $M_1B_1$ and $SD$ the perpendiculars from $M_1$ and $S$ on $EM$. Then comparing the triangles $M_1B_1M$ and $MAE$, we have

$$M_1B_1, \text{ i.e., } SD = \frac{MA \times MM_1}{EM} \times R \sin (bāhu \text{ due to } \text{mandakendra}) \times (\text{radius of corrected } \text{manda epicycle})$$

$$= \frac{(\text{corrected } \text{manda epicycle}) \times R \sin \theta}{80},$$

(1)

where $\theta$ denotes the $bāhu$ due to $\text{mandakendra}$.\(^1\)

Reducing the right-hand side of (1) to the corresponding arc, we get the arc $MS$.

This arc $MS$ has been referred to by Bhāskara I as the arc corresponding to the $\text{mandakendrâphala}$, because it corresponds to $M_1B_1$ which denotes the $\text{mandakendrâphala}$. Generally it is known as $\text{mandaphala}$. It is subtracted from or added to the mean longitude of the planet, according as the $\text{mandakendra}$ is less than or greater than $180^\circ$, as in the case of the Sun and Moon.\(^2\) Thus

true-mean longitude = mean longitude − $\text{mandaphala}$,

according as the $\text{mandakendra}$ is less than or greater than $180^\circ$.

Now consider Fig. 15. Here also $E$ is the Earth and the bigger circle centred at $E$ is the deferent ($\text{kakṣāyṛta}$); $U$ is the planet’s $\text{mandocca}$ (“apogee”) and $V$ the planet’s $\text{sīghrocca}$. $S$ is the position of the true-mean planet on the deferent. The small circle centred at $S$ is the planet’s $\text{sīghra}$ epicycle: it is derived as taught in stanzas 38-39(i). $\text{ST}$ is drawn parallel to $EV$. Then $T$ denotes the position of the true planet. $\text{ET}$ is called the $\text{sīghra-śārīra}$.

\(^1\) The $bāhu$ due to $\text{mandakendra}$ is derived in the same way as in the case of the Sun. The corrected $\text{manda}$ epicycle used in this last result is that divided by $4\frac{1}{2}$.

\(^2\) It may be pointed out that in the case of the Sun and Moon the $\text{mandaphala}$ is the equation of the centre, called $bāhuphala$ by Bhāskara I.
The true planet is assumed to move on the śīghra epicycle with the same angular velocity as the true-mean planet appears to have in the deferent with respect to the śīghrocca. Whereas the true-mean planet appears to move on the deferent (in the clockwise direction) away from the śīghrocca, the true planet is supposed to move on the epicycle, centred at the true-mean planet, in the anti-clock-wise direction, so that the line ST is always parallel to EV.

Let the line ET intersect the deferent at R. Then R denotes the true position of the planet on the deferent. If Τρ be the first point of Aries, then

\[ \angle SE\tau \text{ (or arc } SU\tau) \text{ is the true-mean longitude of the planet, and } \angle RE\tau \text{ (or arc } RU\tau) \text{ is the true longitude of the planet.} \]

The arc RS of the deferent, by which the true longitude of the planet differs from the true-mean longitude, denotes the planet's śīghra correction (usually called śīghraphaia). It is derived as follows:

Let SF, TG, and SH be the perpendiculars drawn from S, T, and S on EV, ES produced and ET respectively.

Now \[ \text{arc } VS = \tau V - \tau S, \]
i.e., \[ \text{śīghrakendra} = (\text{longitude of śīghrocca}) - (\text{longitude of true-mean planet}). \]

Let this śīghrakendra (reduced to bāhu, if necessary) be denoted by ϕ. Then comparing the similar triangles TGS and SFE, we get

\[ TG = \frac{SF \times ST}{ES}, \]

But \[ SF = R \sin \phi, \]
and \[ \frac{ST}{ES} = \frac{\text{śīghra epicycle}}{360} = \frac{\text{corrected śīghra epicycle}}{80}. \]

\[ ^1 \text{As pointed out earlier, this corrected epicycle is divided by 44.} \]
Therefore \[ TG = \frac{R \sin \phi \times \text{(corrected } sîghra \text{ epicycle)}}{80} \]

Again from the similar triangles ESH and ETG, we have

\[ SH = \frac{TG \times ES}{ET}, \]

i.e., \(R \sin \text{(arc RS)}\)

\[ = \frac{R \sin \phi \times \text{(corrected } sîghra \text{ epicycle}}}{80 \times sîghra karna} \times R, \]

Therefore arc RS or \(sîghraphala\) is the arc corresponding to the right hand side of this equality.

This \(sîghraphala\) is added to or subtracted from the true-mean longitude of the planet according as the \(sîghra kendra\) is less than 180° or greater than 180°, because in the former case the true planet is in advance of the true-mean planet and in the latter case the true planet is behind the true-mean planet. Thus

true longitude = true-mean longitude ± \(sîghraphala\),

according as the \(sîghra kendra\) is less than or greater than 180°.

The true longitude of the planet thus obtained was found to differ from the actual longitude determined from observation. \(\text{Āryabhaṭa I}\) supposed that the error was due to the inaccuracy of the \(mandakendra\) (manda anomaly). So to get rid of the error, in the case of the superior planets (Mars, Jupiter and Saturn), he applied in succession (i) half the planet’s \(manda phala\), and (ii) half the planet’s \(sîghra phala\) to the \(manda kendra\) of the planet; and in the case of the inferior planets (Mercury and Venus), he applied half the planet’s \(sîghra phala\) to the \(manda kendra\) of the planet. From the \(manda kendra\) thus corrected, he calculated and applied in succession the \(manda phala\) and the \(sîghra phala\) corrections to the mean longitude of the planet. The same procedure has been followed by the pupils and followers of \(\text{Āryabhaṭa I}\). Hence the rules stated in stanzas 40-44.

The device contemplated by \(\text{Āryabhaṭa I}\) continued to be used by his followers, but it was never very successful. Naturally, it never came into general use. Several other devices were attempted from time to time by later astronomers.

A rule relating to the eccentric theory:

45-46. The wise (astronomer) should apply the eccentric theory here (i.e., in the case of the planets Mars, etc.) also. (Under this theory the \(manda\) and \(sîghra\) operations are as follows:)
To the longitude of the \textit{mandocca} ("apogee"), apply (the \textit{spasta-bhuja} due to the \textit{mandakendra}, as a positive correction) in the manner prescribed above (in stanza 22). From the longitude of the \textit{sighrocca} subtract the \textit{spasta-bhuja} (due to the \textit{sighrakendra}) (as follows):

(When the \textit{sighrakendra} is) in the first and second quadrants, subtract from the longitude of the \textit{sighrocca} the \textit{spasta-bhuja} itself and that subtracted from half a circle (i.e., 180°) respectively; (when the \textit{sighrakendra} is) in the remaining quadrants (i.e., third and fourth), subtract that (\textit{spasta-bhuja}) as increased by half a circle and that (\textit{spasta-bhuja}) subtracted from a circle respectively.

In Fig. 16, let the circle UMN centred at E, the Earth, be the concyclic (\textit{kakśāvṛttā}), the circle centred at C the \textit{manda} eccentric (\textit{manda-pratīvṛttā}), U the planet's \textit{mandocca} (apogee), and M the mean position of the planet. Let MM₁ be parallel to EU; and let S be the point where CM₁ intersects the concyclic, and T' the point where MM₁ and ES produced meet. Then T' is the position of the true-mean planet and S the position of the true-mean planet on the concyclic. If T be the first point of Aries, then

arc $\overline{TU}$ is the true-mean longitude of the planet.

When the mean planet is in the first quadrant beginning with U, as shown in the figure,

$\text{arc } \overline{TU} = \overline{SU} + \overline{US}$,

i.e., true-mean longitude = longitude of the planet's apogee $+$ \textit{spasta-bhuja}.

When the mean planet is in the second anomalistic quadrant, the \textit{spasta-bhuja} is the arcual distance of the true-mean planet from the perigee M. Thus, in this case

\footnote{As in the case of the Sun, arc MU is the \textit{bāhu} or \textit{bhuja} (due to planet's \textit{mandakendra}) and arc SU is the \textit{spasta-bhuja}.}
true-mean longitude = longitude of planet’s apogee
+ (180° − spaṣṭha-bhuja).

Similarly, when the mean planet is in the third anomalistic quadrant,
true-mean longitude = longitude of the planet’s apogee
+ (180° + spaṣṭha-bhuja);
and when the mean planet is in the fourth anomalistic quadrant
true-mean longitude = longitude of the planet’s apogee
+ (360° − spaṣṭha-bhuja).

The spaṣṭha-bhuja is obtained by the following formula as in the case of the Sun:

\[
\text{Rs} \sin (\text{spaṣṭha-bhuja SU}) = \frac{\text{MA} \times \text{ES}}{\text{ET}'} = \frac{\text{Rs} \sin \theta \times \text{R}}{\text{H}},
\]

where \( \theta \) in the bāku or bhuja (due to the planet’s mandakendra), \( \text{R} \) is the radius, and \( \text{H} \) the planet’s distance \( \text{ET}' \) which is called mandakarna and determined by the method of successive approximations as in the case of the Sun. (See stanza 55)

Now consider Fig. 17. The circle VSU, centred at E, is the concyclic, \( \text{V} \) is the śīghrocca, and \( \text{S} \) is the true-mean planet. The circle centred at \( \text{C}_1 \) is the śīghra eccentric. The point \( \text{T} \), where the line through \( \text{S} \) drawn parallel to \( \text{EV} \) meets the eccentric, is the true planet. \( \text{R} \) is the point where \( \text{ET} \) intersects the concyclic. \( \text{A} \) is the first point of Aries.

When the true-mean planet is in the first quadrant beginning with \( \text{V} \) and measured in the clockwise direction as shown in the figure,
true longitude = arc \( \text{T} \text{SR} \) = arc \( \text{T} \text{SV} \) − arc \( \text{VR} \)

Fig. 17 = longitude of the śīghrocca − spaṣṭha-bhuja.
When the true-mean planet is in the second quadrant,
true longitude = longitude of the śīghrocca — (180° — spasṭa-bhuja).
When the true-mean planet is in the third quadrant,
true longitude = longitude of the śīghrocca — (180° + spasṭa-bhuja).
When the true-mean planet is in the fourth quadrant,
true longitude = longitude of the śīghrocca — (360° — spasṭa-bhuja).
The spasṭa-bhuja due to the śīghrocca is determined by the formula:

\[
R \sin \text{(spasṭa-bhuja)} = \frac{SB \times ER}{ET} = \frac{R \sin \phi \times R}{H'}
\]

where \( \phi \) is the bāhu (due to the śīghrakendra), \( R \) the radius, and \( H' \) the
distance ET of the true planet, called śīghrakarna.

A rule for finding the manda-karna and śīghrakarna:

47. Multiply the radius by the (planet's) corrected epicycle
and then divide (the product) by 80; then subtract the quotient
from or add that to the Rsine of the corresponding koṭi (due to
the kendra) in accordance with the quadrant (of the kendra):
and then calculate the (planet's) karna as before.

This method is analogous to that stated for the Sun and Moon in
stanzas 19-20. The important thing to be noted is that in finding the manda-
karna we have to apply the method of successive approximations as in the
case of the Sun and Moon, whereas in finding the śīghrakarna we have to
apply the method only once. The reason for this difference must have
become clear to the reader from the epicyclic and eccentric theories, which
have been explained above in detail.

Procedure to be adopted for finding the true longitude of the
planets under the eccentric theory:

48-54. Add half the difference between the (mean) planet
corrected by the mandocca operation and the mean planet to
or subtract that from the mean planet according as the (mean)
planet as corrected for the mandocca operation is greater or
less (than the mean planet). (The planet thus obtained is call-

\[\text{See infra, stanza 55.}\]
ed the once-corrected planet). Then correct it by the \textit{sihqrocca} operation. (The planet thus obtained is called the twice-corrected planet). Then find the difference between the two planets thus obtained (i.e., the once-corrected and twice-corrected planets); divide that by two; and apply it to the once-corrected planet, as before. Whatever is thus obtained should be again corrected by the \textit{mandooca} operation. Next calculate the difference between the twice-corrected planet, as corrected by the \textit{mandooca} operation, and that (twice-corrected planet). Apply whatever be the difference between the twice-corrected planet as corrected by the \textit{mandooca} operation and the twice-corrected planet to the mean longitude of the planet, as before. That (i.e., the resulting longitude) corrected by the \textit{sihqrocca} operation is the true longitude of the planet.

Thus has been stated the method for finding (the true longitudes of) Mars, Saturn, and Jupiter under the eccentric theory. Now is described the procedure to be adopted in the case of the remaining planets (viz. Mercury and Venus).

(First of all obtain the mean planet as corrected by the \textit{sihqrocca} operation). Then add half the difference between the mean planet corrected by the \textit{sihqrocca} operation and the mean planet to or subtract that from the planet’s \textit{mandooca}, according as the mean planet corrected by the \textit{sihqrocca} operation is less or greater (than the mean planet). Thus is obtained the true \textit{mandooca}. Then find out, by the method under the eccentric theory,\footnote{The method is to find the difference between (i) the mean planet corrected by the \textit{mandooca} operation and (ii) the mean planet.} the correction due to the true \textit{mandooca} for Mercury as well as for Venus. The mean longitudes of Mercury and Venus each corrected for that and thereafter for the correction due to the \textit{sihqrocca} are known as true longitudes of the planets.

The procedure for finding the true longitudes of the superior and inferior planets stated in stanzas 40-44 according to the epicyclic theory has been translated in the above stanzas into the eccentric theory. The results in both cases are the same.
Further instructions relating to mandakarṇa and  ślīghrakarṇa:

55. When the Rsine of the greatest correction (antyaṇahāla) is to be subtracted from the Rsine of the kōṭi (due to the kendra), but subtraction is not possible, then subtract reversely (i.e., the latter from the former).¹ Determine the mandakarṇa by the method of successive approximations (as in the case of the Sun or Moon) and the śīghrakarṇa by a single application of the process (as taught in stanza 47).

In the case of the mandakarṇa, the Rsine of the greatest correction is equal to the radius of the corrected manda epicycle, i.e., to
\[
\frac{(\text{corrected manda epicycle}) \times R}{80}
\]
and in the case of the śīghrakarṇa, the greatest correction is equal to the radius of the corrected śīghra epicycle, i.e., to
\[
\frac{(\text{corrected śīghra epicycle}) \times R}{80}
\]

A rule pertaining to the direct and retrograde motions of a planet:

56-57. Having applied to the longitude of the śīghrocca half the difference between the true and mean longitudes (of a planet) positively or negatively, depending upon (whether) the mean longitude (of the planet is greater or less than the true longitude), determine whether the motion of the planet is vakra or ativakra or whether it is the end of the vakra motion.

The true longitude of the planet having been subtracted from the longitude of the (corrected) śīghrocca, when the difference is 4 signs, the planet is about to take up vakra (retrograde) motion; when 6 signs, it is in ativakra (maximum retrograde) motion; and when 8 signs, it soon abandons the regressive path.²

The difference between the true longitudes of a planet computed for (sunrise on) the day to elapse (i.e., today) and

¹ Reference is to the rule given in stanza 47.
² This rule is found also in ŚīSe, iii. 59; BrSpSl, ii, 50-51; ŚIDVr, I, ii. 42.
for (sunrise on) the day elapsed (i.e., yesterday) is the (true) daily motion (of the planet for the day elapsed).

Hindu astronomers have recognised eight kinds of motion of the planets. According to the Sūrya-siddhānta, these are: (1) vakra (beginning of regression), (2) ativakra (maximum regression), (3) kūṭila (end of regression and beginning of direct motion), (4) manda (slow), (5) manda-tara (slower), (6) sama (mean), (7) śighra (fast), and (8) śighratara (faster). Of these, says the author of the Sūrya-siddhānta, the first three are the different kinds of retrograde motion and the last five the various forms of direct motion. The above stanzas 56 and 57 deal with the three varieties of retrograde motion. The details of the five varieties of direct motion are given by Śripati in his Siddhānta-śekhara. According to him, the motion is said to be “very fast”, when the planet (measured from its śighroca) is in the beginning of the sign Aries or Pisces; “fast”, when in the beginning of Taurus or Aquarius; “mean” when in the beginning of Gemini or Capricorn; “slow”, when in the first half of Cancer or in the last half of Sagittarius; and “very slow”, when in the first half of Sagittarius or in the last half of Cancer.

The following table gives the śigharakendras of the planets when they take up retrograde motion according to various Hindu authorities:

<table>
<thead>
<tr>
<th>Planet</th>
<th>BrSpSi (ii.48), ŚIDVṛ (ii.47), KPṛ (iii.8), ŚiŚe (iii.58), ŚiŚi (i.ii.41)</th>
<th>KKau (ii.23), GLā (iii.15)</th>
<th>MSi (iii.31)</th>
<th>VVSī (ii.30), ŚuŚi (ii.53-54)</th>
<th>PiŚi, KK (iii.8-17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars</td>
<td>163°</td>
<td>163°</td>
<td>163°</td>
<td>164°</td>
<td>164°</td>
</tr>
<tr>
<td>Mercury</td>
<td>145°</td>
<td>145°</td>
<td>145°</td>
<td>144°</td>
<td>146°</td>
</tr>
<tr>
<td>Jupiter</td>
<td>125°</td>
<td>125°</td>
<td>125°</td>
<td>130°</td>
<td>125°</td>
</tr>
<tr>
<td>Venus</td>
<td>165°</td>
<td>167°</td>
<td>166°</td>
<td>163°</td>
<td>165°</td>
</tr>
<tr>
<td>Saturn</td>
<td>113°</td>
<td>113°</td>
<td>113°</td>
<td>115°</td>
<td>133°</td>
</tr>
</tbody>
</table>

1 ii. 12. 2 ŚuŚi, ii.13. 3 iii. 60.
A rule for finding the true daily motion (called जिवाभुक्ति) of the planets:

58-63. Multiply the (planet's) own (mean) daily motion by the current Rsine-difference relating to the मंडोक्का (i.e., the current Rsine-difference corresponding to the मंडकंद्रेण of the planet) and again by the (planet's) own (corrected मन्दा) epicycle; then divide (the product) by the number of minutes in a sign as multiplied by 10 (i.e., by 18000). Add half of that to or subtract that from the (planet's) mean daily motion according to (the law of addition and subtraction in) the (four) quadrants. (Thus is obtained the once-corrected daily motion).

Subtract that from the daily motion of the सिध्रोक्का. Multiply whatever is obtained (i.e., सिध्रकंद्रेणयागतिपहला) by proceeding with the remainder in accordance with the rule "केन्द्रांत्ययोविवा etc." (stated in the previous stanza) by the radius and divide by the सिध्रकर्णा (of the planet); (and reduce the resulting Rsine to the corresponding arc). Add half of that (arc) to or subtract that from (the once-corrected daily motion) in accordance with the law (of addition and subtraction) for the correction due to सिध्रोक्का. (Thus is obtained the twice-corrected daily motion).

Then add the entire of the मंडकंद्रेणयागतिपहला (derived from the current Rsine-difference corresponding to the

---

1. This number is the product of 225 and 80.
2. See supra stanza 5.
3. That is to say, multiply the remainder by the current Rsine-difference corresponding to the सिध्रकंद्रेण of the once-corrected planet and also by the planet's corrected सिध्रा epicycle and divide the product by 18000: the result is the सिध्रकंद्रेणयागतिपहला.
4. Multiply the twice-corrected daily motion by the current Rsine-difference corresponding to the मंडकंद्रेण of the twice-corrected planet and also by the planet's corrected मन्दा epicycle and divide the product by 18000: the result is the मंडकंद्रेणयागतिपहला.
mandakendra of the twice-corrected planet) to or subtract that from the (planet's) mean daily motion (according to the law of addition and subtraction in the four quadrants). Set down the result at two places. At one place (subtract that from the daily motion of the śīghrocca and then) calculate (the arc corresponding to) the śīghrakendraujjāgatiphalā.\(^1\) Add the entire of that (arc) to or subtract that from the result kept at the other place (according to the law of addition and subtraction in the four quadrants). Thus is obtained the desired true daily motion (of the planet).

When the result derived from the śīghra operation (i.e., the arc corresponding to the śīghrakendraujjāgatiphalā) cannot be subtracted from that\(^2\), the difference between the two then denotes the value of the true daily motion and the planet is said by the learned to be retrograde.\(^3\)

This is the method for finding the true daily motion in the case of Jupiter, Saturn, and Mars. Now is being described the method for Venus and Mercury.

Increase or diminish (as usual) the mean daily motion of Venus or Mercury by the entire motion-correction (i.e., mandakendraujjāgatiphalā) determined from the corrected mandakendra and also by that obtained by proceeding according to the rule

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\(^1\) The process is: Multiply the difference obtained after subtraction from the daily motion of the śīghrocca by the current Rsine-difference corresponding to the śīghrakendra and also by the corrected śīghra epicycle and divide that product by 18000; the result is the śīghrakendra-ujjāgatiphalā. Multiply that by the radius and divide by the śīghrakarṇa, and reduce that to the corresponding arc.

\(^2\) That is, the result kept at the other place.

\(^3\) This rule is found also in ŚiDVṛ, I, ii. 38-40.
"ṣīghṛāntya jīvā etc.". This (sum or difference) is the true daily motion (of Venus or Mercury). Thus has been stated the difference of procedure (in the case of the superior and inferior planets).

The daily motion thus obtained is always very nearly equal to the true daily motion and should be made use of in practical calculations.

The above rules relate to the determination of the true daily motion of the planets, Mars, Mercury, Jupiter, Venus, and Saturn, and seem to have been inspired by the rule of Aryabhata I's midnight day-reckoning which has been adopted by Brahmagupta in his Khaṇḍa-khādyaka. They are different from the analogous rules found in the other works on Hindu astronomy.

They have been derived by taking the difference between the longitudes of the planets for two consecutive days as in the case of the Sun and Moon. The rules differ in the case of superior and inferior planets because the methods of finding the true longitudes in the two cases differ.

The daily motion obtained by the application of the above rules is known as jīvābhūkti as in the case of the Sun and Moon. It is probably

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1 That is to say: Multiply the mean daily motion by the current Rṣīne-difference corresponding to the mandakendra determined from the corrected manda (see stanza 53) and also by the corrected manda epicycle and divide the product by 18000: the result is the mandakendra jīvāgati-phala. Add it to or subtract it from the mean daily motion of the planet (as necessary). Subtract the sum or difference thus obtained from the daily motion of the ṣīghrocca. Multiply the difference by the current Rṣīne-difference corresponding to the ṣīgharakendra and also by the corrected ṣīghra epicycle and divide the product by 18000. Multiply that by the radius and divide by the ṣīghrakarna, and reduce that to the corresponding arc. Add it to or subtract it from the mean daily motion already corrected for the mandakendra jīvāgati-phala.

2 See KK (Sengupta), ii. 19; KK (Babua Misra), ii. 26. Also see Prthūdaka’s comm. on this stanza.

3 e. g. by Lalla, ŚīDVṛ, I, ii. 40.

4 See supra stanzas 14-17.
because the rules depend upon the use of the table of Rsine-differences. It is assumed that the Rsines vary very uniformly, so the results obtained from the above rules are only approximate as the author himself admits.

The true daily motion is required for the purpose of computing displacements of the planets. In the case of the Sun and the star-planets (Mars, Mercury, etc.), the daily motion is small enough and not much error is introduced by using the jīvābhukti but in the case of the Moon the daily motion is so much that the use of the jīvābhukti in computing displacements of the Moon may cause serious error. This thing was noticed by the author of the present work himself who in his smaller work, the Laghu-Bhāskarīya, has criticised the jīvābhukti and has preferred the karnabhukti, i.e., the daily motion derived by the use of the instantaneous distance of the planet. Lalla, the author of the Śisya-dhī-vṛddhīda, also has pointed out the above-mentioned discrepancy of the jīvābhukti. In the works of Brahmagupta, Lalla, and Śripati, the rules of finding the true daily motion of the planets are based on the distances of the planets.

The object of devising rules depending on the instantaneous distances of the planets was essentially to obtain the instantaneous velocities of the planets, but the aim was not wholly achieved by the rules given by Brahmagupta, Lalla, and Śripati. For the velocity obtained by their methods turned out to be the same as the mean daily motion of the planet at the intersection of the concentric and the eccentric, which was wrong. An accurate rule for the instantaneous velocity of a planet was given by Mañjula (932 A. D.) and by Āryabhaṭa II (c. 950 A.D.). The method was fully explained by Bhāskara II (1150 A. D.). More accurate rules occur in the Tantra-saṅgraha of Nilakaṇṭha.

Instantaneous velocity is known in Hindu astronomy by the terms tātkālikī-gati, tatkāla-gati, tatkṣaṇa-gati, tatsamayajā-gati, and velā-bhukti.

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1 ii. 14-15.  
2 ŚiDVṛ, I, ii. 43.  
3 The rules are given in BrSpSi, ii. 41-42; ŚiDVṛ, I, ii. 45-46; and ŚiŚe, iii. 42-43 respectively.  
4 See ŚiDVṛ, II, i. 13(ii) and also SiŚi, II, v. 39.  
5 The rules of Mañjula, Āryabhaṭa II, Bhāskara II, and Nilakaṇṭha are given in LMā, ii. 4(ii), MSi, iii. 15 (ii). 27; SiŚi, I, ii. 37, 39; and TS, ii. 51-52 respectively.
A rule for finding the longitudes of the Sun and the Moon at the end of the parva-tithi:

64. Multiply the unelapsed part of the (parva) tithi or the elapsed part of the (next) tithi by the (true) daily motions of the Sun and the Moon and divide (each product) by the difference between the (true) daily motions (of the Sun and Moon). The longitudes of the Sun and the Moon¹ increased or diminished (in the two cases respectively) by the quotients (thus obtained) should be known as the longitudes agreeing to minutes of the Sun and Moon—the causes of the performances of the world.²

By the parva-tithi is meant the fifteenth tithi called purṇimā (i.e., full moon day) or the thirtieth tithi called amāvāsyā (i.e., new moon day). The end of the former occurs when the Sun and Moon are in opposition in longitude, and the end of the latter occurs when the Sun and Moon are in conjunction in longitude.

At the time of opposition of the Sun and Moon, the longitudes of the Sun and Moon differ by six signs but otherwise agree to minutes of arc. At the time of conjunction of the Sun and Moon, the longitudes of the Sun and Moon are exactly the same and therefore agree to minutes of arc. Hence the above rule.

¹ For sunrise on the parva-tithi in the first case and for sunrise on next tithi in the second case.

² The same rule is stated in Śiśi, iv. 8; PSi, vi. 1; MSi, v. 4(ii)-5 (i); Siśe, ili. 84; and Siśi, I, ii. 70; Nilakanṭha (TS, iv. 1-8) and Kamalākara (Śity, ix. 1) have prescribed a successive repetition of the above rule. The method given in LBh, iv. 1 is approximate and simpler.
CHAPTER V
ECLIPSES
(1) ECLIPSE OF THE SUN

Introductory stanza:

1. Now shall be given the solar eclipse as taught by Ācārya Āryabhaṭa. At the beginning of that one should know the determination of the elements (to be used).

Mean distances in *yojanas* of the Sun and Moon:

2. (The mean distance) of the Sun is 459585 (*yojanas*); that of the Moon is 34377 (*yojanas*).

A rule for converting true distances known in minutes into true distances in *yojanas*:

3. These (severally) multiplied by their true distances in minutes (as determined before)¹ and divided by the radius (i.e., 3438 minutes) are known as the true distances in *yojanas* of the Sun and the Moon.²

That is,

Sun's true distance in *yojanas*  
\[= \frac{\text{Sun's mean distance in } *yojanas \times \text{Sun's true distance in minutes}}{\text{Radius}} \]

and Moon's true distance in *yojanas*

Moon's mean distance in *yojanas*  
\[= \frac{\text{Moon's true distance in } *yojanas \times \text{Moon's true distance in minutes}}{\text{Radius}} \]

Diameters of the Earth, the Sun, and the Moon in terms of *yojanas*:

4. The diameter, in terms of *yojanas*, of the Earth has been stated by the learned to be 1050; of the Sun 4410; and of the Moon, 315.

¹ *Vide supra*, Chapter IV, stanzas 9-12 and 19-20.
² This rule is found to occur also in *BrSpSi*, xxi. 31(ii); *ŚiDVr*, I, iv. 5(i); *LBh*, iv. 3; *ŚiŚe*, v. 4 (ii); *ŚiŚi*, I, v. 5(i); *TS*, iv. 10(ii)-11,
The following table gives the diameters and distances of the Sun and the Moon and their ratios according to Bhāskara I, Śrīpati, Bhāskara II, and also according to modern astronomers.

**Comparative table of diameters and distances of the Sun and Moon.**

<table>
<thead>
<tr>
<th></th>
<th>Bhāskara I</th>
<th>Śrīpati</th>
<th>Bhāskara II</th>
<th>Modern, in miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun's diameter in <em>yojanas</em></td>
<td>4410</td>
<td>6522</td>
<td>6522</td>
<td>86400 0</td>
</tr>
<tr>
<td>Sun's distance in <em>yojanas</em></td>
<td>459585</td>
<td>684870</td>
<td>689377</td>
<td>92900000</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.009596</td>
<td>0.009523</td>
<td>0.009461</td>
<td>0.0093</td>
</tr>
<tr>
<td>Moon's diameter in <em>yojanas</em></td>
<td>315</td>
<td>480</td>
<td>480</td>
<td>2160</td>
</tr>
<tr>
<td>Moon's distance in <em>yojanas</em></td>
<td>34377</td>
<td>51566</td>
<td>51566</td>
<td>238900</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.009163</td>
<td>0.009308</td>
<td>0.009308</td>
<td>0.009</td>
</tr>
</tbody>
</table>

This table shows that, although the values of the diameters and mean distances of the Sun and the Moon given by different authorities differ, their ratios are practically the same. It may be pointed out that it is these ratios and not the diameters or distances that are used in the calculation of the eclipses—a fact which is partly responsible for the great accuracy attained by Hindu astronomers in the prediction of the eclipses.

A rule for finding the angular diameters of the Sun and the Moon:

5. The diameters of the Sun and the Moon when (severally) multiplied by the radius and divided by their true distances in *yojanas* become the (angular) diameters in minutes.1

---

1 This rule is found also in *BrSpSi*, xxi. 34(ii); *ŚiDVṛ*, I, iv. 8; *ŚiŚe*, v. 6; and *ŚiŚi I*, v. 7.
ANGULAR DIAMETERS OF SUN, MOON AND SHADOW

That is,

Sun’s diameter in minutes = \frac{\text{Sun’s diameter in } \text{yojanas} \times R}{\text{Sun’s true distance in } \text{yojanas}}

and Moon’s diameter in minutes = \frac{\text{Moon’s diameter in } \text{yojanas} \times R}{\text{Moon’s true distance in } \text{yojanas}}

Formulae for the true (i.e., angular) diameters of the Sun, the Moon, and the shadow¹ in terms of the true daily motions of the Sun and the Moon:

6-7. Five-ninths of the (minutes of the Sun’s true) daily motion and one-twenty-fifth of the (minutes of the Moon’s true) daily motion (treated as minutes) respectively increased and diminished by the seconds equal to one-fourths of themselves are to be known as the true diameters of the Sun and Moon (respectively). One-tenth of (the minutes of) the moon’s true daily motion (treated as minutes) plus one-sixteenth of the same treated as seconds is stated to be the (true) diameter of the shadow.²

That is to say,

(1) Sun’s true diameter = \frac{5}{9} \text{(Sun’s true daily motion in minutes)} + \frac{5}{36} \text{(Sun’s true daily motion in minutes)} \text{ seconds} ;

(2) Moon’s true diameter = \frac{\text{Moon’s true daily motion in minutes}}{\text{25 minutes}} - \frac{\text{Moon’s true daily motion in minutes}}{\text{100 seconds}};

(3) True diameter of the shadow

= \frac{\text{Moon’s true daily motion in minutes}}{\text{10 minutes}} + \frac{\text{Moon’s true daily motion in minutes}}{\text{16 seconds}}.

¹ By the shadow is meant in this chapter the section of the cone of the Earth’s shadow at the Moon’s distance.

² Similar rules occur also in BrSpSi, iv. 6(i) ; KK (Sengupta’s edition), iv. 2(i) ; ŚiDVt, I, iv. 9 ; MŚi, v. 5(ii) ; ŚiSe, v. 9 ; ŚiŚi, I, v. 8-9 ; KPr, v. 2.
The following is the rationale of the above formulae:

From stanza 5, we have

Sun’s true diameter = \( \frac{\text{Sun’s diameter in } yojanas \times R}{\text{Sun’s true distance in } yojanas} \) minutes.

But

\[ \frac{R}{\text{Sun’s true distance in } yojanas} = \frac{\text{Sun’s true daily motion in minutes}}{\text{Sun’s mean daily motion in } yojanas}. \]

Therefore,

Sun’s true diameter

\[ = \frac{(\text{Sun’s diameter in } yojanas) \times (\text{Sun’s true daily motion in minutes})}{\text{Sun’s mean daily motion in } yojanas} \text{ minutes.} \]

Now, according to Bhāskara I, a planet travels through 1,24,74,72,05,76,000 yojanas in 1,57,79,17,500 mean civil days, therefore the mean daily motion of a planet comes out to be 7905·8 yojanas. Hence,

Sun’s true diameter = \( \frac{4410 \times (\text{Sun’s true daily motion in minutes})}{7905·8} \) minutes.

\[ = \frac{5 \times (\text{Sun’s true daily motion in minutes})}{9} \text{ minutes.} \]

\[ + \frac{161 \times (\text{Sun’s true daily motion in minutes})}{7905·8} \times 60 \text{ seconds.} \]

\[ = \frac{5 \times (\text{Sun’s true daily motion in minutes})}{9} \text{ minutes.} \]

\[ + \frac{5 \times (\text{Sun’s true daily motion in minutes})}{36} \text{ seconds.} \]

Similarly,

Moon’s true diameter = \( \frac{315 \times (\text{Moon’s true daily motion in minutes})}{7905·8} \) minutes.

\[ = \text{Moon’s true daily motion in minutes} \]

\[ - \frac{308 \times (\text{Moon’s true daily motion in minutes})}{7905·8 \times 25} \text{ seconds.} \]

\[ = \text{Moon’s true daily motion in minutes} \]

\[ - \frac{25 \times (\text{Moon’s true daily motion in minutes})}{100} \text{ seconds.} \]
The formula for the true diameter of the shadow given in the text depends entirely upon the true daily motion of the Moon whereas it ought to depend upon the true daily motions of the Sun and Moon both. The author obviously takes the mean diameter of the shadow to be that which corresponds to the mean distances of the Sun and the Moon and derives the value of the true diameter of the shadow therefrom by applying the usual process. The *rationale* seems to be as follows:

Mean diameter of the shadow

\[
= \frac{(\text{Sun's diameter} - \text{Earth's diameter}) \times (\text{Moon's mean distance})}{\text{Sun's mean distance}}
\]

\[
= 1050 - \frac{(4410 - 1050) \times 34377}{459585}
\]

\[
= 1050 - \frac{3360 \times 34377}{459585}
\]

\[
= 1050 - 251.3 = 798.7 \text{ yojanas}.
\]

Therefore,

True diameter of the shadow

\[
= \frac{798.7 \times R}{\text{Sun's true distance in yojanas}} \text{ minutes},
\]

\[
= \frac{798.7 \times (\text{Moon's true daily motion in minutes})}{\text{Moon's mean daily motion in yojanas}} \text{ minutes}.
\]

\[
= \frac{798.7 \times (\text{Moon's true daily motion in minutes})}{7905.8} \text{ minutes}
\]

\[
= \frac{\text{Moon's true daily motion in minutes}}{10} \text{ minutes,}
\]

\[
+ \frac{\text{Moon's true daily motion in minutes}}{16} \text{ seconds}.
\]

A rule for the determination of the (śāyana) longitude of the meridian-ecliptic point for the time of geocentric conjunction of the Sun and Moon:

8-11. Now is stated the method for (finding the longitude of) the meridian-ecliptic point. Those proficient in the (astronomical) science should know that the determination (of that) is made with the *āsas* due to right ascension (i.e., with the times in *āsas* of rising of the signs at the equator).
From the _asus_ intervening between midday and the _tithyanta_ ("the time of geocentric conjunction of the Sun and Moon") one should subtract in the forenoon the _asus_ corresponding to the degrees traversed of the sign occupied by the Sun (at the _tithyanta_) and in the afternoon the _asus_ corresponding to the degrees to be traversed. The degrees (traversed or to be traversed) should be (respectively) subtracted from or added to the longitude of the Sun (for the _tithyanta_). The complete signs determined with the help of the _asus_ of the right ascensions of the signs and whatever (fraction of a sign) is obtained by proportion should also be (respectively) subtracted or added by those who know the true principles of the science of time. This (i.e., the longitude thus obtained) is the true (_sāyana_) longitude of the meridian-ecliptic point. So has come out of the mouth of the illustrious (Ācārya Ārya)bhaṭa.¹

The five Rsines relating to the Sun and the Moon:

12. The orbits of the Sun and the Moon being different, the (five) Rsines for them are said to differ.² This (difference) is indicated by the words "_svadṛkkṣepa_ etc." of the Master (Āryabhaṭa I).³

The five Rsines contemplated here are the so called _udayajñā_, _madhyajñā_, _dṛkkṣepajñā_, _dṛgjñā_ and _dṛggatiṇjñā_. Rules for finding these are gives in the next eleven stanzas.

A rule for finding the Sun’s _udayajñā_:

13. Multiply the Rsine of the _bāhu_ due to the (_sāyana_) longitude of the rising point of the ecliptic by (the Rsine of) the (Sun’s) greatest declination and then divide (the product) by (the Rsine of) the colatitude: the quotient is the Sun’s true _udayajñā_.⁴

---

¹ The Sun’s longitude to be used in this rule must be _sāyana_.
² Lalla in his _Śīṣya-dhī-vṛddhida_ takes for simplicity the five Rsines for the Moon to be the same as those for the Sun.
³ _Vide Ā_, iv. 33.
⁴ This rule occurs also in _ŚīDVr_, I, v. 4.
That is

\[ \text{Sun's } udayajyā = \frac{R\sin \lambda \times R\sin \zeta}{R\cos \phi} \]

where \( \lambda \) is the śāyana longitude of the rising point of the ecliptic, \( \zeta \) the greatest declination of the Sun, and \( \phi \) the latitude of the place.\(^1\)

The Sun’s \( udayajyā \) is the Rsine of that part of the local horizon which lies between the east point and the rising point of the ecliptic. It is equal to the Rsine of the \( agra \) of the rising point of the ecliptic and is, therefore, also known as \( udayalagnāgrā \) or simply \( lagnāgrā \).

A rule for finding the Moon’s \( udayajyā \):

14-16(i). The Rsine of (the longitude of) the rising point of the ecliptic minus (the longitude of) the Moon’s ascending node, multiplied by 15 and divided by 191, is the Rsine of the (Moon’s) latitude corresponding to the rising point of the ecliptic. When the declination and (Moon’s) latitude corresponding to the rising point of the ecliptic are of like direction, take their sum; in the contrary case, take their difference. The radius multiplied by the Rsine of the resulting arc (of the sum or difference) and then divided by (the Rsine of) the colatitude gives the the Moon’s \( udayajyā \).\(^2\)

The Moon’s \( udayajyā \) is the Rsine of that part of the local horizon which lies between the east point and the rising point of the Moon’s orbit.

Rules for finding the \( madhyajyās \) of the Sun and the Moon:

16(ii)-18. Calculate the Rsine of the celestial latitude (of the Moon) from the longitude of the meridian-ecliptic point minus the longitude of the Moon’s ascending node.

---

\(^1\) The rationale of this rule is similar to that of the Sun’s \( agra \). See stanza 37 of Chapter III.

\(^2\) This rule is approximate as the declination of the rising point of the Moon’s orbit is not exactly equal to the sum or difference of the declination and Moon’s latitude corresponding to the rising point of the ecliptic.
When the declination of the meridian-ecliptic point and the local latitude are of like direction, take their sum; in the contrary case, take their difference; (and determine the Rsine of that sum or difference). This is the Sun’s madhyājyā which has the same direction as the above sum or difference.

In the case of the Moon, take the sum or difference of the local latitude, the declination (of the meridian-ecliptic point), and the (Moon’s) latitude (corresponding to the meridian-ecliptic point) on the basis of likeness or unlikeness of direction; and then determine the Rsine of the resulting arc. This is the (Moon’s) madhyājyā, which has the same direction as the resulting arc.²

The Sun’s madhyājyā is the Rsine of the zenith distance of the meridian-ecliptic point. The Moon’s madhyājyā is the Rsine of the zenith distance of the meridian point of the Moon’s orbit.

A rule for the determination of the ḍṛkṣepajyās of the Sun and the Moon:

19. Take the product of (the Sun’s or Moon’s) own madhyājyā and udayājyā, then divide (the product) by the radius, and then take the square (of the quotient). Subtract that from the square of the (own) madhyājyā; the square root of that (difference) is known as (the Sun’s or Moon’s) ḍṛkṣepajyā.³

---

¹ The direction of the local latitude is always south; the direction of the declination of the meridian-ecliptic point is north or south according as the meridian-ecliptic point is to the north or south of the equator.

² The rule for the Moon’s madhyājyā is approximate, because the arcual distance between the points where the meridian intersects the ecliptic and the Moon’s orbit is not equal to the Moon’s latitude corresponding to the meridian-ecliptic point.

³ This rule too is approximate and has been criticised by Brahmagupta. (See Br.SpSi, xi. 29, 30). The rationale of the rule is as follows: Let Z be the zenith, M the meridian point of the ecliptic
The Sun’s *drkkṣepajyā* is the Rsine of the zenith distance of that point of the ecliptic which is at the shortest distance from the zenith.\(^1\) The Moon’s *drkkṣepajyā* is the Rsine of the zenith distance of that point of the Moon’s orbit which is at the shortest distance from the zenith.

A rule for finding the *drggjyās* (i.e., the Rsines of the zenith distances) of the Sun and the Moon:

20-22. Calculate the Rsine of the Sun’s zenith distance (*drggjyā*) from the *nādīs* elapsed (since sunrise in the forenoon) or to elapse (before sunset in the afternoon) in accordance with the method stated before.\(^2\) The method for (finding the Rsine of the zenith distance of) the Moon is now being described.

Take the sum or difference of the celestial latitude and declination of the Moon for the time of geocentric conjunction (of the Sun and Moon) according as they are of like or unlike direction. The Rsine of the resulting sum or difference is (the Rsine of) the Moon’s (true) declination. From that calculate the day-radius, the earthsine, and the *asus* of the ascensional difference. With the help of these and the *nādīs* elapsed (since sunrise in the forenoon) or to elapse (before sunset in the afternoon) obtain the Rsine of the zenith distance. (This is the Rsine of the Moon’s zenith distance).\(^3\)

(or Moon’s orbit) and C the point of the ecliptic (or Moon’s orbit) which is at the shortest distance from Z. Then in the triangle ZCM, Rsin ZM = *madhyajyā*, \(\angle ZCM = 90^\circ\), and Rsin \(\angle MZC = udayajyā\). Therefore

\[
\text{Rsin (arc MC)} = (\text{madhyajyā} \times \text{udayajyā}) / R.
\]

The final result is obtained by treating the triangle formed of the Rsines of the sides of the triangle ZCM as a plane right-angled triangle (which assumption is however incorrect).

The same rule occurs also in *ŚiDVṛ, I*, v. 5.

\(^1\) The point of the ecliptic which is at the shortest distance from the zenith is called the nonagesimal or the central ecliptic point.

\(^2\) *Vide supra*, chapter III, stanzas 18-25.

\(^3\) This rule for the Rsine of the Moon’s zenith distance is evidently approximate.
A rule for finding the $dr̄γgatijyāś$ of the Sun and the Moon:

23. Obtain the difference between the squares of the (Sun’s as also of the Moon’s) own $dr̄γyā$ and $dr̄kks̄epajyā$, and then take their square-roots. These (square-roots) are the $dr̄γgatijyāś$ of the Sun and the Moon.\(^1\)

The Sun’s $dr̄γgatijyā$ is the distance of the zenith from the plane of the secondary to the ecliptic passing through the Sun. The Moon’s $dr̄γgatijyā$ is the distance of the zenith from the plane of the secondary to the Moon’s orbit passing through the Moon.

In later astronomical literature, the $dr̄γgatijyā$ is used to mean the Rsine of the altitude of the central ecliptic point (i.e., the point of the ecliptic nearest from the zenith); and the distance of the zenith from the plane of the secondary to the ecliptic is denoted by the term $dr̄γmnatijyā$.

The rationale of the above rule is as follows: In Fig. 18,\(^8\) CS is the ecliptic and K its pole; S is the Sun and Z the zenith; KZC and KS are secondaries to the ecliptic; and ZA is perpendicular to KS. Since the arcs ZC and ZA are perpendicular to CS and AS respectively, therefore

$$(\text{Rsine } ZA)^2 = (\text{Rsine } ZS)^2 - (\text{Rsine } ZC)^2,$$

i.e.,

$(\text{Sun’s } dr̄γgatijyā)^2 = (\text{Sun’s } dr̄γjyā)^2 - (\text{Sun’s } dr̄kks̄epajyā)^2$.

Similarly, in the case of the Moon.

A rule for finding the time of apparent conjunction of the Sun and Moon:

24-27. Severally multiply the own $dr̄γgatijyāś$ (of the Sun and the Moon) by the Earth’s semi-diameter and divide the products by the respective true distances in yojanas. The quotients (thus obtained) are known as the lambanas (of the Sun and the Moon) in terms of minutes (of arc), etc.

Multiply their difference by 60 and divide that by the difference between the true daily motions of the Sun and the Moon. Thus are obtained the $ghaṭīś$ etc. (of the lambana). In the forenoon, subtract them from, and in the afternoon, add

---

\(^1\) This rule occurs also in $SiDV7$, I, v. 6(i).

\(^2\) See *infra*, p. 165.
them to the time of geocentric conjunction of the Sun and Moon. (Then is obtained the first approximation to the time of apparent conjunction).

The lambana computed for the middle of the day is subtracted from the time of geocentric conjunction when the Moon's udayajā is north and added when south.

Repeat this process until the nearest approximation (to the lambana for the time of apparent conjunction) is arrived at.\(^1\)

The corresponding displacements should be given by the learned to (the longitudes of) the Sun and the Moon, as in the case of the tihi (i.e., the time of conjunction of the Sun and the Moon).\(^2\)

The term lambana is the technical term for “parallax in longitude”. When used alone in connection with a solar eclipse it generally stands for the difference between the parallaxes in longitude of the Sun and the Moon.

The above stanzas aim at finding out the time of apparent conjunction of the Sun and Moon. This involves a knowledge of the lambana for that time. For,

\[
\text{time of apparent conjunction} = \text{time of geocentric conjunction} \\
\pm \text{lambana in time for the time of apparent conjunction,}
\]

where + or − sign is taken according as the Sun and the Moon at the time of apparent conjunction lie to the west or east of the central ecliptic point.

The lambana for the time of apparent conjunction depends on the time of apparent conjunction itself. But as the time of apparent conjunction is unknown, the corresponding lambana cannot be obtained directly and recourse is taken to the method of successive approximations stated in the text.

---

\(^1\) The literal translation would run as follows: Repeat this process until the time of apparent conjunction is fixed.

\(^2\) What is meant is that after the first approximation to the time of apparent conjunction is obtained, the corresponding longitudes of the Sun and the Moon should be calculated and the process repeated.
To begin with, the time of geocentric conjunction is taken as the first approximation to the time of apparent conjunction and the corresponding lambana is obtained by the following formula:

$$\text{lambana} = \frac{\text{Moon's drggatiyā } \times \text{ Earth's semi-diameter}}{\text{Moon's true distance in yojanas}} - \frac{\text{Sun's drggatiyā } \times \text{ Earth's semi-diameter}}{\text{Sun's true distance in yojanas}} \text{ minutes.}$$

This formula may be derived as follows:

Consider Fig. 18. CS is the ecliptic, C and S being the central ecliptic point and the Sun at the time of geocentric conjunction (treated as the time of apparent conjunction). K is the pole of the ecliptic and Z the zenith. S' is the position of the Sun as observed from the local place. ZA and S'B are perpendiculars on the secondary to the ecliptic passing through S' (i.e., on KS); S'D is perpendicular to the ecliptic.

In the triangle S'DS right-angled at D, SS' denotes the Sun's parallax in zenith distance and SD denotes the Sun's parallax in longitude (lambana).

From the triangles SBS' and SAZ, right-angled at B and A respectively, we have

$$\text{Rsin (arc BS')} = \frac{\text{Rsin (arc AZ) } \times \text{ Rsin (arc SS')}}{\text{Rsin (arc ZS)}}.$$ 

But $$\text{Rsin (arc BS')} = \text{BS'} \text{ or SD approximately. Therefore,}$$

Sun's lambana = $$\frac{\text{Sun's drggatiyā } \times \text{ Rsin (arc SS')}}{\text{Rsin (arc ZS)}} \text{ approx.}.$$ 

But

$$\text{Rsin (arc SS')} = \frac{\text{Earth's semi-diameter } \times \text{ Rsin (arc ZS)}}{\text{Sun's true distance in yojanas}}.$$ 

Hence

Sun's lambana = $$\frac{\text{Sun's drggatiyā } \times \text{ Earth's semi-diameter}}{\text{Sun's true distance in yojanas}}.$$ 

... (1)
Similarly,

\[ \text{Moon's } \text{lambana} = \frac{\text{Moon's } \text{ørgga } \text{tiyā } \times \text{ Earth's semi-diameter}}{\text{Moon's true distance in } \text{yojanas}} \]

Subtracting (1) from (2), we obtain the required formula.

The \text{lambana} obtained by the above formula is in terms of minutes of arc. When this is multiplied by 60 and divided by the difference between the true daily motions of the Sun and the Moon, it is reduced to the corresponding \text{ghaṭīs}. The \text{lambana} in \text{ghaṭīs} according to the text is to be subtracted from or added to the time of geocentric conjunction according as it occurs in the forenoon or afternoon. In fact, subtraction or addition should be made according as the conjunction occurs to the east or to the west of the central ecliptic point. The law of addition and subtraction given in the text is, however, more convenient in practice.

The rule in stanza 26 shows that the author was aware that at noon the \text{lambana} was different from zero. Still the rule prescribed for the application of that \text{lambana} in that stanza shows that the author did not know the correct law for the addition or subtraction of that \text{lambana}.\footnote{The commentators have, however, tried to interpret the stanza as conveying the desired meaning. For example, Parameśvara writes: “The word \text{indu} here stands for the \text{madhyajīyā}. Therefore, subtraction is to be made when the \text{madhyajīyā} and the \text{udayajīyā} are of like direction. When they are of unlike directions, addition is to be made. This is what has been stated here”. The word \text{indu} means “Moon” and it cannot be interpreted to mean “\text{madhyajīyā}”. There is no scope for such a meaning. Moreover, Parameśvara says that subtraction or addition is to be made according as the \text{madhyajīyā} and \text{udayajīyā} are of like or unlike directions. In fact, there is no reference to any directions, like or unlike. The words used are \text{udak} and \text{daksīne} which mean “in the north” and “in the south” respectively and not “like direction” and “unlike directions” as Parameśvara has supposed.}

The application of the \text{lambana} for the time of apparent conjunction having been thus made to the time of geocentric conjunction, we obtain the second approximation to the time of apparent conjunction. The Sun and the Moon are then calculated for that time and the method is repeated again and again until the nearest approximation to the time of apparent conjunction is obtained.
A rule for finding the true nati:

28.32. Multiply the drkkṣeṣa-pajyās (of the Sun and the Moon), obtained by the method of successive approximations, (severally) by the Earth’s semi-diameter, and divide (the resulting products) by the true distances in yojanas (of the Sun and the Moon respectively); the quotients are in minutes of arc (the parallaxes in latitude of the Sun and the Moon). Take their difference, provided that the madhyajjās of the Sun and the Moon are of like direction; in the contrary case, take their sum; thus are obtained the minutes of the avanati (or nati). (As regards the direction of the nati) take the direction of the Moon’s (madhyajjā).

Multiply the sine of the longitude of the Moon minus the longitude of the Moon’s ascending node by 270, and then divide that product by the Moon’s true distance in minutes. Thus is obtained the true celestial latitude of the Moon. This increased by that (nati) (provided the two are of like direction) is the true nati. In case they are of unlike directions, take their difference. The difference is then called the (true) nati.

Thus is obtained the true avanati (or true nati) for the middle of the eclipse as determined from the drkkṣeṣa and the true latitude of the Sun and the Moon for the time of apparent conjunction (literally, the time of geocentric conjunction corrected for the lambana-difference).

The term nati or avanati means “parallax in latitude”. When used alone in connection with a solar eclipse, it denotes the difference between the parallaxes in latitude of the Sun and the Moon. The true nati is the Moon’s latitude corrected for the nati (i.e., Moon’s apparent latitude). It denotes the arcual distance of the Moon from the Sun’s apparent orbit due to parallax.

The formula given for the nati for the time of apparent conjunction of the Sun and the moon is

\[
\text{nati} = \frac{\text{Moon’s drkkṣeṣa-pajyā} \times \text{Earth’s semi-diameter}}{\text{Moon’s true distance in yojanas}} - \frac{\text{Sun’s drkkṣeṣa-pajyā} \times \text{Earth’s semi-diameter}}{\text{Sun’s true distance in yojanas}}.
\]
The *rationale* of this formula is as follows:

Refer to the previous figure. From the triangles $S'DS$ and $ZCS$, right-angled at $D$ and $C$ respectively, we have

$$R_{\sin \text{ (arc } S'D\text{) or arc } S'D} = \frac{R_{\sin \text{ (arc } ZC\text{) } \times \text{ Rsin (arc } SS'\text{) }}}{R_{\sin \text{ (arc } ZS\text{)}}}.$$

But

$$R_{\sin \text{ (arc } SS'\text{) }} = \frac{\text{Earth's semi-diameter } \times \text{ Rsin (arc } ZS\text{) }}{\text{Sun's true distance in } yojanas}.$$

Therefore,

$$\text{Sun's } nati = \frac{R_{\sin \text{ (arc } ZC\text{) } \times \text{ Earth's semi-diameter }}}{\text{Sun's true distance in } yojanas}$$

$$= \frac{\text{Sun's } drkkṣepajyā }{\text{Sun's true distance in } yojanas} \times \text{ Earth's semi-diameter } \text{ (Equation 1)}.$$

Similarly,

$$\text{Moon's } nati = \frac{\text{Moon's } drkkṣepajyā }{\text{Moon's true distance in } yojanas} \times \text{ Earth's semi-diameter } \text{ (Equation 2).}$$

Subtracting (1) from (2), we get the required formula.

Like the *lambana* for the time of apparent conjunction, the *nati* too for that time is determined by the method of successive approximations.

On the possibility of a solar eclipse:

33. An eclipse of the Sun will not occur if the (true) *nati* is equal to (or greater than) half the sum of the diameters of the Sun and the Moon. It is possible when it (i.e., the true *nati*) is less (than that).

A rule for the determination of the *sparśa-sthityardha* and *mokṣa-sthityardha*:

34-39. Multiply the square root of the difference between the squares of half the sum of the diameters of the Sun and Moon and of the (true) *nati* by 60 and then divide (the product) by the motion-difference (of the Sun and the Moon): thus are obtained the *ghaṭīs* of the *sthityardha*. By these *ghaṭīs*
diminish and increase the time of apparent conjunction as obtained by the method of successive approximations. Then are obtained the (approximate) times for the first and last contacts respectively. Proceeding with them, calculate the (true) Rsines (for the Sun and the Moon), etc., (and obtain the nearest approximations to the lambanas for the times of the first and last contacts). Always add, in the case of a solar eclipse, the nāḍīs of the difference between the lambanas for the first contact and the apparent conjunction to the sthityardha: (the result is the sparśa-sthityardha). Also add the (nāḍīs of the difference between the) lambanas for the apparent conjunction and the end of the eclipse to the sthityardha: the result is the mokṣa-sthityardha. The sthityardhas thus obtained are very accurate: I say this raising my hands aloft (i.e., with firm determination).

When the first contact and the apparent conjunction occur in different halves (eastern and western) of the celestial sphere, then the entire lambana (in nāḍīs) for the time of the first contact is added to the sthityardha. Similarly, when the last contact and the apparent conjunction occur in different halves of the celestial sphere, the entire lambana (in nāḍīs) for the time of the last contact is always added to the sthityardha. The same procedure is also adopted when the apparent conjunction occurs at noon.

The term sthityardha means "half the duration (of an eclipse)". The sparśa-sthityardha is the interval of time between the first contact and the apparent conjunction. The mokṣa-sthityardha is the time-interval between the apparent conjunction and the last contact.

A rule for the determination of the vimardārdha:

40. The nāḍīs of the vimardārdha are to be determined from the square root of the difference between the squares of (i) the difference between the semi-diameters of the eclipsed and eclipsing bodies and (ii) the Moon’s latitude (corrected for the nati).
The term vimardārdha means "half the duration of the totality of an eclipse", i.e., the time-interval between the immersion and the apparent conjunction or between the apparent conjunction and the emersion. The time-interval between the immersion and the apparent conjunction is called the sparṣa-vimardārdha and that between the apparent conjunction and the emersion is called the mokṣa-vimardārdha.

The above stanza gives the method for finding the first approximation to the vimardārdha in minutes of arc. The corresponding nādis are obtained by multiplying that by 60 and dividing by the difference between the true daily motions of the Sun and the Moon. The nearest approximations to the sparṣa- and mokṣa-vimardārdhas are obtained as in the case of the sthityardhas.

A rule for knowing the time of actual visibility of the first contact in the case of a solar eclipse:

41. On account of the brightness of the Sun, the time of (actual visibility of) the first contact (in the case of a solar eclipse) is the (computed) time of the first contact plus the time corresponding to the minutes of arc amounting to one-eighth of the Sun's diameter.

Āryabhaṭa I says: "When the moon eclipses the Sun, even though one-eighth part of the Sun is eclipsed this is not perceptible because of the brightness of the Sun and the transparency of the Moon's circumference." 1

A rule for finding the magnitude and direction of the aksa-valana:

42-44. Multiply the reversed-sine of the asus intervening between midday and the titihi (i.e., the time of the first contact, the middle of the eclipse, or of the last contact) by (the Reine of) the (local) latitude and divide that (product) by the radius. Reduce the resulting Rsine to the corresponding arc (called aksa-valana) and determine its direction.

When the above asus exceed (those corresponding to) a quadrant, add the Rsine of the excess to the radius and operate as before; and then find the direction.

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1 A, iv. 47.
The direction (of the *akṣa-valana*) for the middle of the ecliptic is the same as that for the first contact.

In the forenoon, the directions (of the *akṣa-valana*) in the eastern and western halves of the disc (of the eclipsed body) are north and south respectively. To the west of the sky (i.e., in the afternoon), the *akṣa-valana* is always of the contrary direction.\(^1\)

The great circle of the celestial sphere which has the centre of the eclipsed body as one of its poles is called the horizon of the eclipsed body. Suppose that the prime vertical, the equator, and the ecliptic intersect the horizon of the eclipsed body\(^2\) at the points \(E_1, T_1,\) and \(Y_1\) respectively towards the east of the eclipsed body. Then the point \(E_1\) is called the east point of the horizon of the eclipsed body; the arc \(E_1T_1\) (which denotes the deflection of the equator from the prime vertical on the horizon of the eclipsed body) is called the *akṣa-valana*; and the arc \(T_1Y_1\) (which denotes the deflection of the ecliptic from the equator along the same circle) is called the *ayana-valana*.

The formula for the *akṣa-valana* stated in the text is

\[
R\sin (akṣa-valana) = \frac{R\text{versin } H \times R\sin \phi}{R},
\]

where \(H\) denotes the hour angle (*nata-kāla*) and \(\phi\) the local latitude.

This formula is based on inference. Early Hindu astronomers noted that when the eclipsed body was at the intersection of the meridian and the equator, the Rversed-sine of the hour angle was zero and the Rsine of the *akṣa-valana* was also zero; and that with the increase of the Rversed-sine of the hour angle the Rsine of the *akṣa-valana* also increased; and further that when the eclipsed body was at the intersection of the horizon and the equator, the Rversed-sine of the hour angle was equal to its maximum value \(R\) and the Rsine of the *akṣa-valana* was also maximum and equal to the Rsine of the latitude. They, therefore, supposed that the Rsine of the *akṣa-valana* varied as the Rversed-sine of the hour angle, and to obtain the Rsine of the *akṣa-valana* for the desired time they made use of the

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\(^1\) The same rule is found also in *ŚiDvṛ, I*, iv. 23 and *ŚiŚe, v. 18.*

\(^2\) By the eclipsed body here is meant the position of the eclipsed body on the ecliptic.
proportion: When the Reversed-sine of the hour angle amounts to R, the Rsine of the aksa-valana equals the Rsine of the latitude, what then would be the value of the Rsine of the aksa-valana corresponding to the Reversed-sine of the desired hour angle? Hence the above formula.

The above formula can be easily seen to be incorrect. It was first modified by Brahmagupta, who replaced Rversin H by Rsin H.¹ Better and accurate formulae were given by Bhāskara II.²

The rules for the direction of the aksa-valana can be seen to be true by means of a diagram.

A rule for the determination of the magnitude and direction of the ayana-valana:

45. The (Sun’s) declination determined from the Reversed-sine of the longitude of the Sun or Moon as increased by three signs (treated as the Rsine of the bhuja) is the ayana-valana. Its direction in the eastern half (of the disc of the eclipsed body) is the same as that of the ayana (of the Sun or Moon);³ in the other half, it is contrary to that.⁴

That is,

$$\text{Rsin'(ayana-valana)} = \frac{\text{Rsin } C \times \text{Rversin } (\lambda + 90^\circ)}{R},$$

where C denotes the obliquity of the ecliptic and $\lambda$ the sāyana longitude of the eclipsed body (the Sun or Moon).

This formula also is based on inference. The proportion used is the following: "When Rversin ($\lambda + 90^\circ$) is equal to R, the Rsine of the ayana-valana is equal to the Rsine of the obliquity of the ecliptic, what then would be the Rsine of the ayana-valana corresponding to the desired value of the Reversed-sine?"

¹ See BrSpSi, iv. 16.
² See SiŚi, I, v. 20-21(i); II, viii. 68; and II, viii. 66(ii)-67.
³ The ayana of a planet is north or south according as it is in the half-orbit beginning with the (sāyana) sign Capricorn or in that beginning with the (sāyana) sign Cancer.
⁴ This rule occurs also in ŠiDVṛ, I, iv. 25 and SiŚe, v. 20.
This formula also is incorrect. It was modified by Brahmagupta,\textsuperscript{1} who replaced Rversin ($\lambda + 90^\circ$) in the formula by Rsin ($\lambda + 90^\circ$). An accurate expression for the *ayana-valana* was given by Bhāskara II (1150 A. D.).\textsuperscript{2}

A rule for finding the value of the resultant *valana* (*spaṣṭa-valana*) for the circle drawn with half the sum of the diameters of the eclipsed and eclipsing bodies as radius:

46-47. When they (i.e., the *akṣa-valana* and the *ayana-valana*) are of unlike directions, take the difference of their arcs; in the contrary case, take their sum.\textsuperscript{3} Multiply the Rsine of that (sum or difference) by half the sum of the diameters of the eclipsed and eclipsing bodies and divide (the product) by the radius. Add whatever is thus obtained to the (Moon’s true) *nati*, provided that they are of like directions; in the contrary case, take their difference: the resulting sum or difference is the *valana*.

The sum or difference of the *akṣa-valana* and the *ayana-valana* according as they are of like or unlike directions gives the so called *spaṣṭa-valana*, i.e., the amount of deflection of the ecliptic from the prime vertical on the horizon of the eclipsed body. When the Rsine of that is multiplied by half the sum of the diameters of the eclipsed and eclipsing bodies and the product divided by the radius, we get the corresponding deflection on the circumference of the circle drawn with half the sum of the diameters of eclipsed and eclipsing bodies as radius. The sum or difference of this and the Moon’s true *nati* according as the two are of like or unlike directions gives the distance of the centre of the eclipsing body from the east-west line passing through the centre of the eclipsed body. So has been assumed in the above rule.

The direction in the rule for adding or taking the difference of the reduced *spaṣṭa-valana* and the Moon’s true *nati* is wrong. The two quantities should be kept separately and laid off properly one after the other (in the projected figure).

\textsuperscript{1} See *BrSpSl*, iv. 17.
\textsuperscript{2} See *SiŚi*, I, v. 21(ii)-22(i).
\textsuperscript{3} This rule occurs also in *BrSpSl*, iv. 18 (i) and *ŚiDVṛ*, I, iv. 26.
The next twenty stanzas relate to the projection (i.e., graphical representation) of an eclipse.

A method for ascertaining the centre of the eclipsing body for the times of the first and last contacts (called the sparsa-bindu and the mokṣa-bindu respectively):

48-53. By means of a pair of compasses, whose smooth and large body is graduated with aṅgulas and subdivisions thereof and which is embellished by the pointed end of a smoothened chalk-stick placed into its mouth, construct on the ground a circle with half the measure, in aṅgulas, of the eclipsed body as radius, and another (concentric circle) with half the sum of the diameters of the eclipsed and eclipsing bodies as radius. (Through the common centre) then draw the east-west line and, with the help of a fish-figure, the north-south line. From the centre then lay off the valana (for the first or last contact) towards the north or south (according to its direction); draw a fish-figure there; and (through its head and tail) carefully\(^1\) draw a line to meet the outer circle. At the meeting point of the outer circle and that line set a point. (This is the centre of the eclipsing body for the time of the first or last contact). From that point stretch out a line to reach the centre. Where this line is seen to intersect the circumference of the eclipsed body, lies the point of contact or separation of the Sun’s disc.

One minute of arc should be taken as equivalent to one half of an aṅgula or as it appears in the sky.

A method for determining the centre of the eclipsing body for the middle of the (solar) eclipse (called the madhya-bindu):

54-57. The valana for the middle of the eclipse is taken

\(^{1}\) The word “carefully” indicates that when the valana corresponds to the first contact, the line should be drawn towards the west or east according as the eclipse is solar or lunar; but when the valana corresponds to the last contact, the line should be drawn in the contrary direction.
without the addition or subtraction of the \textit{nati}. When that and the \textit{nati} are of like direction, the \textit{(madhya)valana} should be laid off towards the east; when they are of unlike directions, it is stretched out from the centre towards the west. With the help of a fish-figure (drawn about the point thus obtained), a line should then be drawn in the direction of the \textit{nati}. From the meeting point of that with the outer circle, the intelligent should then draw a line to reach the centre (of the circle).\footnote{1} The \textit{nati} should then be laid off from the centre along that line. At the end of that lies the centre of the eclipsing body at the middle of the eclipse (i.e., the \textit{madhya-bindu}). The two points (already marked) are the centres of the eclipsing body for the times of the first and last contacts (i.e., the \textit{sparsa-bindu} and \textit{(mokṣa-bindu)}).

When the \textit{nati} (for the middle of the eclipse) is of south direction, it should be laid off towards the south; when it is of north direction, it is laid off towards the north.

Points of difference of procedure in the case of a lunar eclipse:

58. This (i.e., the previous rule) is the method for the middle of the eclipse in the case of a solar eclipse. In the case of a lunar eclipse, the points of the first contact, the middle of the eclipse, and the last contact should be clearly indicated reversely.

That is, in the case of a lunar eclipse, the following procedure should be adopted: To begin with, the \textit{madhya-valana} should be laid off towards the west or east, according as the \textit{madhya-valana} and the \textit{nati} are of like or unlike directions. With the help of a fish-figure drawn about the point thus obtained a line should then be drawn through that point in the direction contrary to the direction of the Moon's latitude. From the meeting point of that line with the outer circle a line should then be drawn to reach

\footnote{1} This line is perpendicular to the ecliptic at the time of the middle of the eclipse.
the centre of the circle. The Moon's latitude for the middle of the eclipse should then be laid off from the centre along that line.

Construction of the phase of the eclipse for the time of the middle of the eclipse:

59-60. Quickly cut off the eclipsed body by means of a pair of compasses (one leg of) which is placed at the madhyabindu and (the other leg of) which is stretched out by half the specified true measure of the eclipsing body. The portion thus cut off (in case the eclipse is partial), or the entire disc of the eclipsed body drawn (likhitam) on the projection (in case the eclipse is total)—all of that is clearly seen (in the sky) in that way at the time of the middle of the eclipse.

By the world likhita, says Paramesvara, is meant a total eclipse, or, in case the Moon's latitude is zero and the disc of the eclipsed body is larger, an annular eclipse.

Construction of the path of the eclipsing body:

61. Draw (an arc of) a circle passing through the three points set down above with the help of two fish-figures: this is the path of the eclipsing body. The phase of the eclipse for the given time is ascertained (by determining the position of the eclipsing body on that path and drawing its disc with its centre) there.¹

A method for calculating the phase of the eclipse for the given time:

62-63. Multiply the difference between the (true) daily motions of the Sun and the Moon by the sthityardha-ghatis² minus the given time (istakāla) and divide the product by sixty. Add the square of the quotient to the square of the Moon's nati (corrected latitude) (for the given time) and then take the square root of that (sum). This (square root) is (the length of)

¹ This rule occurs also in ŚiDV, I, iv. 34.
² That is, ghāṭis corresponding to the sthityardha.
the needle joining the centres of the eclipsed and eclipsing bodies at the given time in the case of solar and lunar eclipses. (Subtract that from half the sum of the diameters of the eclipsed and eclipsing bodies). The remainder is the phase of the eclipse for the given time.¹

By the given time is meant the time elapsed since the first contact or the time to elapse before the last contact.

Construction of the phase of an eclipse for the given time:

64-65. Stretch out a fine bamboo needle (equal in length to that joining the centres of the eclipsed and eclipsing bodies at the given time) obliquely from the centre in such a way that its end may fall on the so-called path of the eclipsing body. Taking the centre at that point, cut off the eclipsed body by means of a circle drawn with half the diameter of the eclipsing body as radius. As much portion is thus cut off, so much of the eclipsed body is seen to be eclipsed (in the sky).

Construction of the phase of a (solar) eclipse for the time of immersion or emersion:

66-67. The shityardha in terms of minutes of arc minus the minutes of the vimardardha is the means for projecting the phase of the eclipse for that time (i.e., immersion or emersion). The Sun’s disc should be cut off with the help of that (i.e., that should be laid off from the sparśa or moksā bindu along the path of the eclipsing body towards the centre and the point thus obtained should be treated as the centre of the eclipsing body for that time). The disc of the Sun should be cut off by means of a pair of compasses. The seizure (of the Sun) occurs on the western side of the disc and the separation on the eastern side.

The remaining chapter deals with the lunar eclipse.

¹ This rule is found also in BrSpSt, iv. 11-12; ŚiDVṛ, I, iv. 19-20; SiŚe, v. 14.
(2) ECLIPSE OF THE MOON

Points of difference of procedure in the case of a lunar eclipse:

68-70. Similarly, in the case of the Moon, which is the mirror for the face of the directions and exhibits (or bears) all excellent phases and whose round body looks like the face of a damsel, too, the (ten) Rsines should be found out. The points of difference (in the procedure) are being stated.

The (five) Rsines relating to the shadow should be determined as arising from the Sun’s orbit. (In place of the Sun’s distance) the Moon’s distance is stated to be the divisor. The lambana, determined as in the case of the Sun, should be added or subtracted reversely.

Use of parallax in a lunar eclipse prescribed in the above stanzas is obviously wrong. Paramesvara comments: “Thus in the case of a lunar eclipse also, the use of parallax is stated here. This, say the proficient in Sphérics, is improper”.

It must be mentioned that the application of parallax in the case of a lunar eclipse has not been prescribed in any other work on Hindu astronomy, not even in the smaller work of the present author.

A rule for the determination of the diameter of the shadow, i.e., the diameter of the section of the Earth’s shadow where the Moon crosses it:

71-73. Multiply the Sun’s (true) distance in yojanas by the Earth’s diameter and divide by the difference of their diameters: thus is obtained the length of the Earth’s shadow. Or, multiply the Sun’s (true) distance in yojanas by 5 and divide by 16: the result is called the length of the Earth’s shadow,

From that (length of the Earth’s shadow) subtract the Moon’s distance. Multiply the remainder by the Earth’s diameter and divide (the product) by the length of the (Earth’s) shadow. Multiply the resulting quotient by the radius and divide (the product) by the Moon’s distance (in yojanas): this is (the diameter of) the shadow (in minutes of arc).
That is,
the diameter of the shadow
\[
\frac{\text{length of Earth's shadow} - \text{Moon's distance}}{\text{length of Earth's shadow}} \times \text{Earth's diameter},
\]
where
\[
\text{length of Earth's shadow} = \frac{\text{Sun's distance} \times \text{Earth's diameter}}{\text{Sun's diameter} - \text{Earth's diameter}}.
\]

This result is approximate and is the same as that given by Āryabhaṭa I.\(^1\) It is usually derived by the following method (called "the lamp and shadow method"):

Consider Fig. 19. S is the centre of the Sun and E that of the Earth. SA and EB are drawn perpendicular to SE and denote the semi-diameters of the Sun and the Earth respectively. BL is parallel to ES. O is the point where SE and AB produced meet each other.

Hindu astronomers compare SA with a lamp-post, EB with a gnomon, and EO with the length of the shadow cast by the gnomon due to the light of the lamp. Consequently, they call EO "the length of the shadow".

The triangles BEO and ALB are similar, therefore
\[
\frac{EO}{BE} = \frac{BL}{LA} = \frac{SE}{SA - EB}.
\]

Therefore
\[
EO = \frac{SE \times BE}{SA - EB} = \frac{SE \times 2BE}{2SA - 2EB} = \frac{\text{Sun's distance} \times \text{Earth's diameter}}{\text{Sun's diameter} - \text{Earth's diameter}}.
\]

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\(^1\) See \(\overline{A}\), iv. 39-40. This rule is found also in \(BrSpSi\), xxiii. 8-9; and \(ŚiDVr\), I, iv. 6 (ii)-7.
Now consider Fig. 20. AC and BD are the diameters of the Sun and the Earth. BOD is the shadow-cone\(^1\), O its vertex. S and E are the centres of the Sun and the Earth. M is the point where the Moon crosses the shadow cone. MN is perpendicular to the axis of the shadow-cone and denotes the diameter of the section of the shadow cone where the Moon crosses it. It is called the diameter of the shadow.

The triangles MON and BOD are similar, so that

\[
\frac{MN}{KO} = \frac{BD}{EO}.
\]

Therefore,

\[
MN = \frac{KO \times BD}{EO} = \frac{(EO - EK) \times BD}{EO} = \frac{(EO - EM) \times BD}{EO} \text{ approx.}
\]

i.e., the diameter of the shadow

\[
= \left\{ \text{length of Earth's shadow} - \text{Moon's distance} \right\} \times \text{Earth's diameter}
\]

length of Earth's shadow

The approximations made in the above procedure are obvious.\(^2\)

The diameter thus obtained is in yojanas. To reduce it to minutes of arc we have to multiply it by the radius (i.e., 3438') and divide by the Moon's distance in yojanas.

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\(^1\) Approximately.

\(^2\) The formula for the diameter of the shadow stated above was modified and refined by Muniśvara (1646 A. D.) and Kamalākara (1658 A. D.). The latter astronomer gave an accurate expression for the diameter of the shadow (in SiTV, ix. 29-33).
Views of other astronomers regarding the calculation of a lunar eclipse:

74. Others give instruction in the lunar eclipse without the use of the ten Rsines, because it causes little difference in the result (and is simpler). There (i.e., in the rule stated by them) the sparśa- and mokṣa-sthityardhas arising from (the Moon’s latitude for) the time of opposition of the Sun and Moon (lit. middle of the eclipse) should be operated upon by the method of successive approximations.

Details of the process of successive approximations referred to above:

75-76. Multiply the (true) daily motion (of the Moon) by the time (in ghatīs) of the sthityardha and divide the product by 60. Subtract the quotient from or add that to the Moon’s (true) longitude for the time of opposition (of the Sun and Moon), according as it is the first or last contact. From that find out the Moon’s latitude; and therefrom (again) calculate the sthityardha. (In this way repeat the above process again and again until two successive approximations agree). This is the process of successive approximations. Similar again is the process of (determining) the (sparśa- and mokṣa-) vimardārdhas.¹

A rule relating to the direction of the Moon’s latitude to be taken in the projection of a lunar eclipse:

77. While projecting an eclipse (of the Moon), the best amongst the learned should take the direction of the Moon’s latitude to be north when it is south, and south when it is north.

¹ For details see our notes on LĪh, iv. 10-12. The rule stated here is found also in BrSpSi, iv. 8-9; ŚiDVṛ, I, iv. 14-16; ŚiŚe, v. 12-13; ŚiŚi, I, v. 12-13.
Concluding stanza in praise of the methods for calculating and projecting an eclipse that have been stated above:

78. This procedure regarding the Sun, the Moon, and the shadow, which has come down (to us) by tradition, has been stated here having cast off pride and jealousy. A learned person who acquires a mastery of this (procedure) shall become a (proficient) astronomer well versed in all astronomical methods.
CHAPTER VI

RISING, SETTING AND CONJUNCTION OF PLANETS.

A rule relating to the visibility-correction known as \textit{akśa-\ddot{k}kkarma}:

1-2(i). Multiply the Moon's latitude for the desired time by the Rsine of latitude of the local place, and divide (the product) by the Rsine of the colatitude; whatever is thus obtained, say the learned, should be subtracted (from the Moon's longitude) in the case of rising of the Moon (i.e., in the eastern hemisphere) and added (to the Moon's longitude) in the case of setting of the Moon (i.e., in the western hemisphere), provided that the Moon is to the north of the ecliptic (i.e., if the Moon's latitude is north). When the Moon is to the south of the ecliptic, the law (of addition and subtraction) is the reverse.\footnote{The same rule is found to occur in \textit{BrSpSi}, vi. 4; \textit{ŚīDVṛ}, I, vii. 3(ii); \textit{MSi}, vii. 4; \textit{ŚiŚe}, ix. 7.}

The correction stated in the first three stanzas of this chapter is called "the visibility-correction (\ddot{k}k-karma)". When we apply this correction to the true longitude of the Moon, we obtain the longitude of that point of the ecliptic which rises or sets with the apparent Moon.

The visibility-correction is generally broken up into two components: (1) the visibility-correction due to the latitude of the local place (\textit{akśa-\ddot{k}kkarma}), and (2) the visibility-correction due to the Sun's northward or southward course (i.e., ecliptic-deviation) (\textit{ayana-\ddot{k}kkarma}).

Let Fig. 21 represent the celestial sphere for the local place. \textit{SEN} is the eastern horizon and \textit{Z} the zenith; \textit{\ddot{E}} is the equator and \textit{P} its north pole; \textit{T} is the ecliptic and \textit{K} its north pole. Suppose that the Moon is rising at the point \textit{M}' on the horizon. Let \textit{M} be the point where the secondary to the ecliptic (\textit{kadambaprotavṛtta}) drawn through \textit{M}' intersects the ecliptic, \textit{L} the point where the hour circle (\textit{dhruvaprotavṛtta})
drawn through M' intersects the ecliptic, and T the point where the horizon intersects the ecliptic. Then the arc MT of the ecliptic denotes the total visibility-correction; the arc ML denotes the visibility — correction due to ecliptic-deviation (ayana-dṛkkarma); and the arc LT denotes the visibility correction due to the latitude of the local place (akṣa-dṛkkarma). The visibility-correction for a planet is defined in the same manner.

The correction stated in the above stanzas is the akṣa-dṛkkarma for the Moon. The formula stated is

$$akṣa-dṛkkarma = \frac{R \sin \phi \times \text{Moon's latitude}}{R \cos \phi}$$

where $\phi$ is the latitude of the local place.

This formula is approximate. Let A be the point where the diurnal circle through M intersects the hour circle through M', B the point where the diurnal circle through M intersects the horizon, and C the point where the hour circle through B intersects the diurnal circle through M'. Then proceeding as for finding the earthsine, it can be easily shown that

$$\text{arc } CM' = \frac{R \sin \phi \times R \sin (\text{arc } BC)}{R \cos \phi} \approx \frac{R \sin \phi \times \text{Moon's latitude}}{R \cos \phi} \approx$$

---

1 The point L is called ayana-graha or āyana-graha. See ŚiDVṛ, I, vii. 2,4.
2 T is called dṛg-graha. See ŚiDVṛ, I, vii. 4.
It follows that the formula given in the text actually gives an approximate value of the arc CM' or AB.¹

The rule stated in the text has been generally used in the cases where the latitude of the body concerned is small. In the cases of fixed stars whose latitudes may be considerable, a more accurate rule is prescribed.²

When the Moon's latitude is north, the longitude of the point T is smaller or greater than the longitude of the point L according as the Moon M' is rising or setting; and when the Moon's latitude is south, the longitude of the point T is respectively greater or smaller; hence the rule of addition and subtraction stated in the text.

A rule relating to the visibility correction known as ayana-dr̄kkarma:

2(ii)-3. Divide the product of the reversed-sine of the Moon's longitude diminished by three signs, the Rsine of the Sun's greatest declination, and the Moon's latitude by the square of the radius. Whatever is thus obtained, say the learned, should be subtracted from the Moon's longitude provided that her ayana and latitude are of like direction; in the contrary case, that result should always be added to the Moon's longitude.³

¹ That this formula gives an approximate value of arc AB may be demonstrated as follows:

Since MM' is small, we may treat the triangle M'B'A as plane. Then from the triangle M'B'A, we have

$$AB = \frac{\text{Rsine} \angle BM'A \times M'A}{\text{Rsine} \angle M'B'A}$$

$$= \frac{\text{Rsine} \angle BM'A \times M'M}{\text{Rsine} \angle M'B'A}$$

$$= \frac{\text{Rsine} \phi \times \text{Moon's latitude}}{\text{Rsine} \phi}$$

approx.

See E. Burgess, Śiśi, vii. 7-12, notes,

² See BrSpSi, x. 18-19; ŚiDVṛ, I, xi. 12-13; and ŚiŚi, I, vii. 6. Bhāskara II has given a slightly modified formula for small latitudes also. See ŚiŚi, I, vii. 7. The most accurate formula for the aksa-dr̄kkarma occurs in ŚiTV, vii. 103-104.

³ This rule occurs also in ŚiDVṛ, I, vii. 2-3(i) and ŚiŚe, ix. 4, 5. The same rule in a modified form occurs in BrSpSi, vi. 3; x. 17 and in MSi, vii. 2, 3. More accurate rules occur in ŚiŚi, I, vii. 4, 5 and in ŚiTV, vii. 77-80.
That is

\[
\text{ayana-\textsuperscript{d}ṛkkarma} = \frac{\text{Rs} \times \text{Sin } (M - 90^\circ)}{\text{R} \times \text{R}} \times \text{Moon's latitude},
\]

where \( M \) denotes the Moon's (sāyana) longitude and \( \xi \) the Sun's greatest declination.

This formula is also approximate. Referring to the previous figure, we have

\[
\text{arc MA} = \frac{\text{Rs} \times \text{Sin } \angle \text{MM'A} \times \text{Sin } (\text{arc MM'})}{\text{R}} \quad \text{approx.}
\]

\[
= \frac{\text{Rs} \times \text{Sin } \angle \text{KMP} \times \text{Sin } (\text{arc MM'})}{\text{R}} \quad \text{approx.}
\]

\[
= \frac{\text{ayana-valana} \times \text{Moon's latitude}}{\text{R}} \quad \text{approx.}
\]

\[
= \frac{\text{Rs} \times \text{Sin } (M - 90^\circ) \times \text{Sin } \xi \times \text{Moon's latitude}}{\text{R} \times \text{R}} \quad \text{approx.}
\]

on substituting the value of the \textit{ayana-valana}.\footnote{Vide supra, chapter V, stanza 45, p. 171,}

The formula stated in the text, therefore, is an approximate value of the arc MA, or ML, which is the \textit{ayana-\textsuperscript{d}ṛkkarma}.

When the \textit{ayana} and latitude of the Moon are of like directions, the longitude of the point \( L \) is smaller than the longitude of the point \( M \); and when the \textit{ayana} and latitude of the Moon are of unlike directions, the longitude of the point \( L \) is greater than the longitude of the point \( M \); hence the rule of addition and subtraction stated in the text.

The visibility-corrections should be applied as follows. The true longitude of the Moon (which corresponds to the longitude of the point \( M \) of the ecliptic) should be first corrected for the \textit{ayana-\textsuperscript{d}ṛkkarma}: the resulting longitude corresponds to that of the point \( L \) of the ecliptic. This is technically called the polar longitude of the Moon. This polar longitude should then be corrected for the \textit{aṅga-\textsuperscript{d}ṛkkarma}: the longitude thus obtained corresponds to that of the point \( T \) of the ecliptic, which rises (or sets) with the Moon's disc. This is technically called the longitude of the visible Moon (\textit{dṛśya-candra}).

In the text the order of the corrections is reversed. The difference is negligible.

\footnote{Vide supra, p. 171 (footnote).}
A rule relating to the visibility of the Moon:

4-5(i). The Moon’s longitude, which is obtained in this way after the application of the above-mentioned (visibility) corrections, is stated by the learned to be the longitude of the visible Moon (i.e., the longitude of that point of the ecliptic which rises with the Moon).

When the prānas (of the oblique ascension) due to the degrees intervening between the Sun and the (visible) Moon, reduced to ghaṭis, amount to two, then the Moon is seen to rise in the clear, cloudless, starry sky after sunset.

The latter part of the above passage relates to the visibility of the Moon, or, in other words, the heliacal rising of the Moon. On the fifteenth lunar day of the dark half of the month, the Moon comes near the Sun from behind and is lost in his splendour. After about two days it is beyond the limit of invisibility and is again seen in the sky after sunset, being in advance of the Sun.

In order to see whether the Moon will be visible on the first or second lunar day of the light half of the month, one should calculate the (sāyana) longitude of the Sun for sunset on that day and also the (sāyana) longitude of the Moon corrected for the visibility corrections for the same time. If the oblique ascension of the part of the ecliptic lying between the Sun and the Moon thus obtained is equal to or greater than two ghaṭis, the Moon will be visible after sunset that day, otherwise not. Similarly, in order to test whether the Moon will be visible in the night just before she sets heliacally on the fourteenth or fifteenth lunar day of the dark half of the lunar month, one should calculate the (sāyana) longitude of the Sun for sunrise following that night and also the (sāyana) longitude of the Moon corrected for the visibility corrections for the same time. If the oblique ascension of the part of the ecliptic lying between the Sun and the Moon thus obtained is equal to or greater than two ghaṭis, the Moon will be seen before sunrise, otherwise not.

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1 Prāṇa is the same as asu.

2 Both sāyana.

3 This rule is found to occur also in PSI, v. 3; BrSpSi, vi. 6; x. 32; ŚiDVṛ, I, vii. 5; SiSe, ix. 8(i), 13.
A rule for calculating the phase of the Moon:

5(ii)-7. (In the light half of the month) multiply (the diameter of) the Moon's disc by the Rversed-sine of the difference between the longitudes of the Moon and the Sun (when less than a quadrant) and divide (the product) by the number 6876: the result is always taken by the astronomers to be the measure of the illuminated part (of the Moon). When the difference between the Moon and the Sun exceeds a quadrant, then the Moon's illuminated part is calculated from the Rsine of that excess increased by the radius.¹

After full Moon (i.e., in the dark half of the month) the unilluminated part of the Moon is determined from the Rversed-sine or Rsine of (the excess over six or nine signs respectively of) the difference between the longitudes of the Moon and the Sun in the same way as the illuminated part is determined (in the light half of the month).

Let the longitude of the Moon minus the longitude of the Sun be denoted by $D$. Then according to the above rule—

1. In the light half of the month, the illuminated part of the Moon
   \[
   \text{Rversin } D \times \text{Moon's diameter} \div 6876
   \]
   if $D < 3$ signs, i.e., if it is the first quarter of the month; and
   \[
   \left[ \text{R} + \text{Rsine } (D - 90^\circ) \right] \times \text{Moon's diameter} \div 6876
   \]
   if $D > 3$ signs, i.e., if it is the second quarter of the month.

2. In the dark half of the month, the unilluminated part of the Moon
   \[
   \text{Rversin } (D - 180^\circ) \times \text{Moon's diameter} \div 6876
   \]
   if $D > 6$ signs, i.e., if it is the third quarter of the month; and
   \[
   \left[ \text{R} + \text{Rsine } (D - 270^\circ) \right] \times \text{Moon's diameter} \div 6876
   \]
   if $D > 9$ signs, i.e., if it is the last quarter of the month.

¹ This rule is found to occur also in BrSpSi, vii. 11(ii)-12 and ŠidVr, I, ix. 12.
Consider Fig. 22. The sphere centred at M is the Moon’s globe, and E is the centre of the Earth. The lines MS' and ES (which are approximately parallel to each other) are directed towards the Sun. Half the globe of the Moon bounded by the circle ABCD and lying towards the Sun is illuminated by the rays of the Sun, and half the globe bounded by the circle LBTD and lying towards E is visible from the Earth. An observer on the Earth will, therefore, see only that part of the Moon’s illuminated surface which lies between the semicircles BCD and BTD. In fact, he will see the projection of that on the plane of the circle LBTD. Let BZD be the projection of the semicircle BCD on the plane LBTD. Then the observer will see that part of the Moon’s disc illuminated by the Sun which lies between BTD and BZD. This illuminated part of the Moon’s disc is measured by the length ZT of the Moon’s diameter.

From the figure, it is evident that
\[ \angle CMZ = \angle FMS' = \angle MES, \]
so that from the plane triangle CZE right-angled at Z, we have
\[ MZ = \frac{R \cos \angle CMZ \times MC}{R}, \]
Therefore
\[ ZT = MT - MZ = \frac{(R - R \cos \angle CMZ) \times MC}{R} = \frac{R \versin \angle CMZ \times MC}{R} = \frac{R \versin \angle MES \times MC}{R}. \]

Hence the rule.

A rule for the determination of the Moon’s true declination, i.e., the declination of the centre of the Moon’s disc:

8. Take the sum of the arcs of the Moon’s declination and (celestial) latitude when they are of like directions; in the
contrary case, take their difference. Then take the Rsine of that
(sum or difference). (This is the Rsine of the Moon's true declination).\footnote{This rule occurs also in BrSpSi, vii. 5; ŚiDVṛ, I, viii. 2; SiŚe, x. 7. It is obviously approximate. A better and more accurate rule occurs in SiŚI, I, vii. 3 and 13.} From that calculate the \textit{nādis} of the ascensional difference of the Moon.

The Moon's true declination is used in finding the radius of the
Moon's diurnal circle and the Moon's ascensional difference. The pro-
cess is the same as that for the Sun.

A rule for the determination of the base (bāhu) and upright
(koṭi) to be used in the graphical representation of the elevation
of the Moon’s horns, when the calculation is made in the
first quarter of the month for sunset:

9-12. (Calculate the longitudes of the Sun and the visible
Moon for sunset on the day of calculation). By the help of the
\textit{asus} intervening between the Sun and the (visible) Moon
always find out, in the manner stated before, the Rsine of the
Moon’s altitude. Then divide the product of the Rsine of
Moon’s true altitude (thus obtained) and the Rsine of the
(local) latitude by the Rsine of the colatitude: thus is obtained
the Moon \textit{sāṅkvagra}, which is always to the south of the Moon’s
rising-setting line. Then multiply (the Rsine of) the Moon’s
true declination by the radius and divide (the resulting product)
by the Rsine of the colatitude: thus is obtained the so called
Rsine of the \textit{aṅrā} of the (apparent) Moon lying to the north
or south (of the ecliptic). Take their sum (i.e., the sum of the
Rsines of the Moon’s \textit{sāṅkvagra} and \textit{aṅrā}) when they are of
like directions, and the difference when they are of unlike
directions. Then reversely add or subtract the Rsine of the Sun’s
\textit{aṅrā}. Then is obtained the true value of the Moon’s base
(bāhu). Then Rsine of the Moon’s altitude is the upright (koṭi).

The \textit{asus} intervening between the Sun and the visible Moon are the
\textit{asus} of the oblique ascension of that part of the ecliptic which lies between
the Sun and the visible Moon. These correspond to the time to elapse before moonset.

The Moon’s agrā and śaṅkvagra are defined in the same way as in the case of the Sun.\(^1\)

The base (bāhu or bhuja) for a planet is the distance of the foot of the perpendicular dropped from the planet on the plane of the horizon from the east-west line. It is equal to

\[ \text{śaṅkvagra} \pm \text{Rsin (agrā)} \]

+ or – sign being taken according as the śaṅkvagra and the Rsine of the agrā are of like or unlike directions.

The true value of the Moon’s base (usually called spāṣṭa-bāhu or spāṣṭa-bhuja) denotes the north-south distance between the projections of the Sun and the Moon on the plane of the horizon. It is equal to

\[ \text{Moon’s base} \pm \text{Sun’s base,} \]

+ or – sign being taken according as the bases of the Sun and the Moon are of unlike or like directions. When the Sun is on the horizon as in the case contemplated in the above stanzas, is is equal to

\[ \text{Moon’s base} \pm \text{Sun’s agrā.}^2 \]

The upright denotes the difference between the Rsines of the altitudes of the Moon and the Sun. In the present case, the Sun’s altitude is zero, so that the upright is equal to the Rsine of the Moon altitude.

The base and the upright defined above will be required in the stanzas below.

Method for the graphical representation of the elevation of the lunar horns in the first quarter of the month at sunset:

13-17. To the north or south of the Sun is (to be laid off) the (true) base (according to its direction); and to the east\(^3\) (of the point thus obtained) is (to be laid off) the upright; the line which joins the ends of the base and the upright is called the hypotenuse. (Taking the centre) at the meeting point of the hypotenuse and the upright, draw the Moon’s disc. The

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\(^1\) Vide supra, chapter III, stanzas 37 and 54, pp. 84 and 93.

\(^2\) The Sun’s base in this case is the same as the Sun’s agrā.

\(^3\) The upright is laid off towards the east because in the light half of the month the Moon is towards the east of the Sun.
hypotenuse is the east-west line of that (Moon's disc); through
the middle of that (i.e., through the centre of the Moon's disc)
draw the north-south line. At the extremities of the north-south
line mark two points on the periphery of the Moon's disc. (Then
lay off the Moon's illuminated part) along the hypotenuse (from
the west point) towards the interior of the Moon's disc and
mark there the point of illumination. Thereafter always draw
a circle passing through the (above-mentioned) three points.
The portion lying between that (circle) and the (periphery of the)
Moon's disc (lying towards the Sun) is called the illuminated
part (of the Moon). The elevation, depression, or horizon-
talness of the Moon's horns, in whatever unit be it measured (in
the figure), is clearly perceived in the sky (as in the figure).\footnote{This rule is approximate. For other rules, see BrSpSi, vii. 7-10; ȘiDVr, I, ix; ȘiSi, I, ix.}

In Fig. 23, AB is the base and MA the upright. Then, according
to Bhāskara I, B denotes the Sun's centre and M the Moon's centre. The
circle NESW centred at M is the Moon's disc, the points N, E, S, and W
being the north, east, south, and west points on its periphery. The
measure of the illuminated part of the Moon, IW, is laid off from W to-
wards M and an arc of a circle
is drawn through N, I, and S.\footnote{The point I is called "the point of illumination" (sitabindu).}
The shaded portion lying be-
 tween this arc and the arc NWS
is the illuminated part of the
Moon's disc. The cusps at N
and S are called the Moon's horns. The figure shows that
in the present case the case the
northern horn is higher than
the southern one,

Representation of the elevation of the lunar horns at any other
time instead of sunset in the first quarter of the month:

18. This (above) method is to be followed at sunset. At
(any other) given time, all calculations such as the determination
of the Rsine of the zenith distance of the Moon for that time are prescribed to be made with the setting point of the ecliptic (taken for the Sun).

The only difference in this case is that the time to elapse before moonset, instead of being found out from the asus intervening between the Moon and the Sun (as was done in the previous case), should be found out in this case from the asus intervening between the Moon and the setting point of the ecliptic, or, as the commentator Paramesvara says, from the asus intervening between the rising point of the ecliptic and the point six signs in advance of the Moon. The asus correspond to oblique ascension as in the previous case.

Representation of the elevation of the lunar horns in the second quarter of the month:

19. (When the calculation relating to the elevation of the Moon’s horns is made) after the eighth lunar day, the rising point of the ecliptic itself should be regarded as the Sun. And under that assumption should be made the calculation of the Rsine of the Moon’s altitude, etc., with the exception of the calculation of the measure of the illuminated part (of the Moon’s disc).

A rule for the determination of the Rsine of the Moon’s altitude to be used in connection with the elevation of the lunar horns:

20. The Rsine of the Moon’s altitude should be calculated from the asus intervening between the Sun and the Moon, or between the rising or setting point of the ecliptic and the Moon subject to the time of calculation, the asus being those obtained by applying the rule once and not successively.

A rule telling that the above calculations pertaining to the elevation of the lunar horns relate to the first half of the month only:

21. In this manner, at sunset or any other time, with the help of the longitudes of the Sun, Moon and the Moon’s ascending node, should be made this calculation relating to the Moon till the fifteenth lunar day: so has been said.
ELEVATION OF THE LUNAR HORNS

A rule telling how many \( \text{nādis} \) before or after sunset will the Moon be seen to rise on the full Moon day:

22. Diminish the \( \text{nādis} \) (due to the oblique ascension of the part of the ecliptic) intervening between the Sun and the (visible) Moon (at sunset on the full moon day) (from or) by (the \( \text{nādis} \) of) the length of the day: so many \( \text{nādis} \) before or after sunset is the Moon seen (to rise on the full moon day). \(^1\)

A rule relating to the representation of the elevation of the lunar horns in the dark half of the month:

23-25. After the end of the (light) fortnight, the Moon, lying above the horizon, is drawn by using the measure (of the Rsine of the Moon's altitude) computed from (the \text{asus} due to the oblique ascension of the part of the ecliptic intervening between the visible Moon and) the rising point of the ecliptic at the given time. The upright is laid off towards the west\(^2\); the base is laid off along the north-south line (in its proper direction); and the hypotenuse-line is stretched out from the end of that (base) to meet the end of the upright. Then from the east point (of the Moon's figure) lay off the measure of the (Moon's) illuminated part along the hypotenuse-line within the figure of the Moon; or, from the west point (of the Moon's figure), lay off the (measure of the Moon's) unilluminated part.

A rule telling how to do the same at sunrise in the dark half of the month:

26. Or, perform the operation, stated above, concerning the Moon's illuminated or unilluminated part at sunrise with the \text{asus} intervening between the (visible) Moon and the Sun at that time. The time of moonrise will now be told.

\(^1\) This rule gives an approximate time of moonrise. In order to obtain the nearest approximation to the correct time of moonrise use should be made of the method of successive approximations. See infra s tanzas 31-35.

\(^2\) Because in the dark fortnight the Moon is to the west of the Sun.
A rule for getting the duration of the Moon's visibility at night in the light half of the month (I quarter):

27. In the light fortnight, find out the asus due to oblique ascension (of the part of the ecliptic) intervening between the Sun and the (visible) Moon (at moonset) both increased by six signs, by the method of successive approximations. These give the duration of visibility of the Moon (at night) (or, in other words, the time of moonset).\(^1\)

The process of successive approximations may be explained as follows: Compute the (sāyana) longitudes of the visible Moon and the Sun for sunset and increase both of them by six signs. Then find out the asus \((A_1)\) due to the oblique ascension of the part of the ecliptic lying between the two positions thus obtained. Then \(A_1\) asus denote the first approximation to the duration of the Moon's visibility at night. Then calculate the displacements of the Moon and the Sun for \(A_1\) asus and add them respectively to the longitudes of the visible Moon and the Sun for sunset and increase the resulting longitudes by six signs; and then find out the asus \((A_2)\) due to the oblique ascension of the part of the ecliptic lying between the two positions thus obtained. Then \(A_2\) asus denote the second approximation to the duration of the Moon's visibility at night. Repeat the above process successively until the successive approximations to the duration of the Moon's visibility agree to \(vighaṭis\).

The time thus obtained is in terms of civil reckoning. If, however, the use of the Moon's displacement alone be made at every stage, the time obtained will be in terms of sidereal reckoning.

A rule for finding the time of moonrise in the dark half of the month (III quarter):

28. Thereafter (i.e., in the dark half of the month), the Moon is seen (to rise) at night (at the time) determined by the asus (due to oblique ascension) derived by the method of successive approximations from the part of the ecliptic intervening between the Sun as increased by six signs and the (visible) Moon as obtained by computation, (the Sun and the Moon both being those calculated for sunset).\(^2\)

\(^1\) Cf. \(ŚūŚi\), x. 2-4.  \(^2\) Cf. \(ŚūŚi\), x. 5.
TIME OF MOONRISE IN THE DARK FORTNIGHT

In the night, the time is measured since sunset.

Details of the method of successive approximations contemplated in the above rule:

29-31. Determine the time in asus (due to the oblique ascension of the part of the ecliptic) intervening between the rising point of the ecliptic and the (visible) Moon computed for sunset. (This is the first approximation to the required time). Now calculate the positions of the rising point of the ecliptic and the (visible) Moon for that time; and then determine the asus intervening between those positions again. In case the longitude of the (visible) Moon is greater than that of the rising point of the ecliptic, add these asus to the time obtained above; in the contrary case, subtract them. (This is the second approximation to the required time). Repeat this process successively until the successive approximations to the time, the longitude of the rising point of the ecliptic, and the longitude of the (visible) Moon are (severally) equal (up to vighatīs or minutes). At the time ascertained by this procedure for the Moon, the Moon is seen (to rise) in the night filling (the space in) all the directions with her rays.

The above rule is based on the fact that at moonrise the longitudes of the visible Moon and the rising point of the ecliptic are the same.

An alternative rule for finding the time of moonrise in the dark half of the month (III quarter):

32-33. Find out the asus due to the oblique ascension of the part of the ecliptic lying from the setting Sun up to the (visible) Moon; and therefrom subtract the length of the day. (This approximately gives the time of moonrise as measured since sunset). Since the Moon is seen (to rise) at night when so much time, corrected by method of successive approximations, is elapsed, therefore the asus obtained above should be operated upon by the method of successive approximations.
Details of the method of successive approximations contemplated in the above rule:

34. Find out the displacements of the Sun and the Moon for the ghatīs (corresponding to the approximate time) obtained above and add them to the longitudes of the Sun and the (visible) Moon respectively; then determine the ghatīs (due to the oblique ascension of the part of the ecliptic) intervening between them; and then from those (ghatīs) subtract the length of the day. (Thus is obtained the second approximation to the required time). Then find out the the displacements of the Sun and the Moon corresponding to (the ghatīs of) the remainder (and proceed as above again and again until the successive approximations agree to vighatīs).

An analogous rule for finding the time of moonrise in the light half of the month (II quarter):

35-36. (In the light half of the month) when the measure of the day exceeds the nādīs (due to the oblique ascension of the part of the ecliptic) lying between the Sun and the (visible) Moon (computed for sunset), the moonrise is said to occur in the day when the residue of the day (i.e., time to elapse before sunset) is equal to the ghatīs of their difference. (In this case) the longitudes of the Sun and the (visible) Moon should be diminished by their displacements determined by proportion from the nādīs (of the residue); and then should be obtained the asus (due to the oblique ascension of the part of the ecliptic) between the Sun and the (visible) Moon (thus obtained). These asus should then be operated upon by the method of successive approximations.

Another rule for getting the time of moonrise in the dark half of the month (IV quarter):

37-38. Determine the asus (due to the oblique ascension of the part of the ecliptic lying) from the (visible) Moon at sunrise up to the rising Sun; then subtract the corresponding displacements (of the Moon and the Sun) from them (i.e., from
the longitudes of the visible Moon and the Sun computed for sunrise); and on them apply the method of successive approximations (to obtain the nearest approximation to the time between the visible Moon and the Sun computed for moonrise, i.e., between the risings of the Moon and the Sun). The Moon, who is like a looking glass for the face of the directions, rises as many asus before sunrise as correspond to the nāḍās obtained by the method of successive approximations.

A rule for the determination of the time of the meridian passage of the Moon, and the longitudes of the Moon and the meridian-ecliptic point at that time:

39. Infer by your intellect the time when the meridian-ecliptic point and the Moon are together. Then, by the method of successive approximations, find out the nearest approximations for that time, the longitude of the Moon, and the longitude of the meridian-ecliptic point (for that time).

Assuming that the rising point of the ecliptic is three signs in advance of the meridian-ecliptic point, the time to elapse before or elapsed since the Moon is on the meridian is the same as the time to elapse before or elapsed since the point of the ecliptic three signs in advance of the Moon is on the horizon. Therefore in order to get an approximate time when the Moon occupies the meridian-ecliptic point one may proceed as follows: First calculate the longitudes of the Sun, the Moon, and the rising point of the ecliptic with the help of the given time. Then increase the longitude of the Moon by three signs and find the time due to the oblique ascension of the part of the ecliptic lying between the rising point and the Moon as increased by three signs. The time thus obtained is the approximate time to elapse before or elapsed since the meridian passage of the Moon. From this calculate the time of the meridian passage of the Moon.

Details of the method of successive approximations contemplated in the above rule:

40. Determine the nāḍās intervening between the Moon and the meridian-ecliptic point (for the time determined by inference) with the help of the times of rising of the signs at Laṅkā. When (the longitude of the Moon is) less (than the
longitude of the meridian-ecliptic point), subtract the resulting \(\text{nādīs}\) from those corresponding to the inferred time; when greater, addition is prescribed. (For the time thus obtained calculate the longitudes of the Moon and the meridian-ecliptic point and find the \(\text{nādīs}\) intervening between them with the help of the right ascensions of the signs as before; and then repeat the above process successively until the nearest approximation to the time of meridian passage of the Moon is obtained).

A rule for the determination of the Rsine of the Moon’s meridian zenith distance:

41. By this process is obtained the Moon when she is on the meridian (lit. when her longitude is equal to that of the meridian-ecliptic point). From her celestial latitude and declination, and from the (local) latitude is determined the Rsine of her meridian zenith distance.

First obtain the Moon’s true declination by rule 8 above; then apply the following formula:

Moon’s meridian zenith distance = local latitude ± true declination, + or – sign being taken according as the Moon is to the south or to the north of the equator.

A rule regarding the elevation of the horns of the half-risen or half-set Moon:

42. The determination of the elevation of the horns of the half-risen or half-set Moon is made with the help of the \(\text{agrā}\) of the rising or setting point of the Moon’s orbit.

When the Moon is rising or setting, its base is obviously equal to the \(\text{agrā}\) of the rising or setting point of the Moon’s orbit.

The text does not say anything about the base and depth of the Sun lying below the horizon but these elements have to be calculated and made use of in the above-mentioned determination.

Procedure to be adopted in the case of the planets:

43. This (above-mentioned) procedure should be adopted in the case of the nectar-rayed Moon; the same process is prescribed for all the planets also.
The remainder of this chapter deals exclusively with the planets.

Minimum distances of the planets from the Sun when they are visible:

44. Venus is visible when it is 9 degrees away from the Sun; Jupiter, Mercury, Saturn, and Mars are observed when they are respectively further away by two degrees in succession (i.e., when they are respectively 11°, 13°, 15°, and 17° away from the Sun).

45. Venus, which moves in its proper orbit but appears retrograde, is visible, due to profusion of its rays, when it is (only) 4½ or 4 degrees away from the Sun.

The degrees above are "the degrees of time" (called kālabhāga). One degree of time is equivalent to 60 asus. Thus Venus is visible in the east if the time taken by the part of the ecliptic between the Sun and Venus to rise above the eastern horizon amounts at least to $9 \times 60$ asus; and in the west, if the time taken by the part of the ecliptic between the Sun and Venus to set below the western horizon, or the time taken by the diametrically opposite part of the ecliptic to rise above the eastern horizon, amounts at least to $9 \times 60$ asus. It may be pointed out that a sign sets in the same time that the seventh, i.e., the diametrically opposite sign, takes to rise.

According to Lalla, Mercury and Venus, when in regression, are visible when they are respectively 12 and 8 degrees distant from the Sun. According to Śripati, Mercury and Venus, when near their apogees, are visible when they are respectively 14 and 10 degrees distant from the Sun; and when in regression, they are visible when respectively 12 and 8 degrees distant from the Sun.

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1 The same degrees of visibility are prescribed also in BrSpSi, vi. 6; x. 32; ŚiDVt, I, vii. 5 (i); and ŚiŚe, ix. 8 (i), 12.
2 When Mercury or Venus is in retrograde motion, it is nearer to the Earth and so its size is a little enlarged.
3 Venus in both the cases being that corrected for the visibility corrections.
4 ŚiDVt, I, vii. 5 (ii).
5 ŚiŚe, ix. 9. The Greek astronomer Ptolemy (150 A. D.) also considered the heliacal rising and setting of the planets and defined the limits of visibility of each planet when in the sign Cancer (i.e., when the equator and the ecliptic are nearly parallel). His limits are; for Saturn, 14°; for Jupiter, 12°45'; for Mars, 14°30'; and for Venus and Mercury, in the west, 5°40' and 11°30' respectively. Vide Syntaxis, xiii. 7-9.
A rule telling us (1) how to convert the degrees of time into vighatīs, and (2) how to determine the degrees of time between the Sun and a planet:

46-47. These degrees of time when multiplied by ten are called vighatīs. (When the planet is seen) in the east, they are determined from (the oblique ascension of) the sign occupied by the Sun and the planet; (when the planet is visible) in the west, they are determined from (the oblique ascension of) the seventh sign (as measured from the sign occupied by the Sun and the planet).¹ (The process is as follows): Divide the oblique ascension of the sign occupied by the Sun and the planet (or of the seventh sign, as the case may be) as multiplied by the degrees of the difference between the longitudes of the planet and the Sun by 30. If the resulting time is equal to (or greater than) that stated (for that planet), the planet will be seen to rise (heliacally).

The longitude of the planet is that corrected for the visibility-corrections.

CONJUNCTION OF PLANETS

Definition of the “divisor” to be used later:

48. The sīghra-karaṇa as multiplied by the mandocca-karaṇa (or manda-karaṇa) should be divided by the radius: the result thus obtained is called the “divisor”.²

This “divisor” denotes the distance between the Earth and a planet (bhū-tārāgraha-vivara). The above rule for the divisor was probably derived by proportion as follows: “If the radius of the sīghra concentric denotes the manda-karaṇa, what will the sīghra-karaṇa stand for? The result is the geocentric distance of the planet, the so called “divisor”.

¹ Cf. ŚīDvṛ, I, vii. 5 (iv).
² Cf. ŚīDvṛ, I, x. 1.
A rule relating to the determination of the time and the common longitude of two planets when they are in conjunction in longitude:

49-51. If one planet is retrograde and the other direct, divide the difference of their longitudes by the sum of their daily motions; otherwise (i.e., if both of them are either retrograde or direct), divide that by the difference of their daily motions: thus is obtained the time in terms of days, etc., after or before which the two planets are in conjunction (in longitude). The velocity of the planets being different (literally, manifold) (from time to time), the time thus obtained is gross (i.e., approximate). One, proficient in astronomical science, should, therefore, apply some method to make the longitudes of the two planets agree to minutes. Such a method is possible from the teachings of the precepter or by day to day practice (of the astronomical science).1

The method to be used here is obviously the method of successive approximations.

A rule relating to the computation of the celestial latitude of a planet when it is in conjunction with another planet:

52-53. Diminish the longitude of the planet in conjunction with another planet by the degrees of (the longitude of) the ascending node (of that planet); by the sine of that multiply the greatest latitude (of the planet) and divide (the product) always by the (corresponding) “divisor” (defined in stanza 48): thus is obtained the latitude of Jupiter, Mars, or Saturn. In order to find the latitudes, north or south, of the remaining planets (Mercury and Venus), subtraction (of the degrees of the longitude of the ascending node) should be made from the longitude of the planet’s sīghrocca.2

The longitude of the planet to be used in the above rule is really the heliocentric longitude and not the geocentric longitude. Brahmagupta

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1 Cf. BrSpSi, ix. 5-6; ŚiDVṛ, I, x. 7-9 (i); ŚiŚe, xi. 12-13.
2 This rule occurs also in ŚiDVṛ, I, x. 10, 9 (ii).
RISING, SETTING AND CONJUNCTION OF PLANETS

(628 A. D.) has therefore prescribed the use of the true-mean longitude of the planet in the case of Mars, Jupiter and Saturn, and that of the longitude of the planet’s śighrocca as corrected for the planet’s mandaphala in the case of Mercury and Venus.¹

A rule relating to the distance between two planets which are in conjunction in longitude:

54-55. When the latitudes of the two planets (in conjunction) are of unlike directions, their sum is the (angular) distance between them. When their latitudes are of like directions, the minutes of the distance between them are obtained by taking their difference.²

The (linear) distance between the two planets (in conjunction) should be announced by those proficient in the processes of planetary conjunction by taking a minute as equivalent to one-fourth or one-half of an āṅgula, whichever agrees with the phenomenon observed in the sky.

According to the commentator Paramesvara, one minute of the distance between the two planets is equal to one-half or one-fourth of an āṅgula, according as the two planets are or are not near the horizon.

Brahmagupta has criticised the longitudinal conjunction of the planets.³ He favours horizontal conjunction which occurs when the two planets are on the same secondary to the prime vertical, because it can be easily observed.

Diameters of the planets in minutes of arc:

56. Having (first) divided 32 by 5, divide the same number (i.e., 32) again and again by the same (5) as increased by itself in succession (i.e., by 10, 15, 20, and 25): the results thus obtained are known as the minutes of the diameters of Venus, Jupiter, Mercury, Saturn, and Mars respectively.

¹ See BrSpSt, ix, 9. Also see SiSi, ii. 56-57; SiSe, xi. 15; and SiŚi, II, vi. 20-25(i).
² This rule occurs also in ŚiDVr, I. x. 11; KPr, vii. 8; and has been quoted by Brahmagupta in BrSpSt, ix 11, and by Śripati in SiSe, xi. 18.
³ In BrSpSt, ix. 11-12. Also see SiŚe, ix. 19-20.
According to Āryabhaṭa I, the diameter of the Moon is 315 yojanas, and the diameters of Venus, Jupiter, Mercury, Saturn, and Mars are respectively one-fifth, one-tenth, one-fifteenth, one-twentieth, and one-twenty-fifth of the diameter of the Moon (at the Moon’s mean distance). It follows that

\[
\text{the diameter of a planet in minutes = } \frac{\text{diameter of the planet in yojanas } \times R}{\text{Moon's mean distance in yojanas}}
\]

\[
= \frac{\text{diameter of the planet in yojanas}}{10} \approx \text{approx.}
\]

\[
= \frac{\text{diameter of the Moon in yojanas}}{10 \times D} \approx \text{approx.,}
\]

where \(D = 5, 10, 15, 20,\) or \(25,\) according as the planet is Venus, Jupiter, Mercury, Saturn, or Mars.

\[\frac{32}{D} \approx \text{approx.}\]

Hence the rule in the text.

Definition of the “dividing numbers” for the planets:

57. (Severally) multiply the yojanas of the Moon’s (mean) distance by the same numbers (i.e., by 5, 10, 15, 20 and 25): the result, in each case, is the “dividing number”, in terms of yojanas, used in the determination of the lambana and nati (for the respective planets).

The “dividing numbers” denote the mean distances of the planets under the assumption that the diameter of each of them is 315 yojanas (the same as that of the Moon).

A rule for finding the true distance of a planet, assuming 315 yojanas for its diameter, in terms of yojanas:

58 (i). These (above-mentioned) “dividing numbers” become accurate when multiplied by the “divisor” and divided by the radius.

\[A, \text{ i. 7.}\]
The obvious proportion is: When the radius (i.e., 3438') corresponds to the planet's mean distance in yojanas, what will the divisor (i.e., the true distance of the planet in minutes) correspond to? The result is the true distance of the planet in terms of yojanas.

A rule relating to the determination of the true values of the diameters of the planets in minutes:

58 (ii). So also become the minutes of the diameters when divided by the "divisor" and multiplied by the radius.\footnote{The same rule occurs in Śidvṛt, I, x. 4.}

The remaining processes concerning the occultation of one planet by another:

59-60. The determination of the ten Rśines (viz. madhyajyā, drkksepajyā, drggatijyā, drjyā and udayajyā—five for each of the two planets concerned) and other remaining determinations should be made as in the case of the Moon. The Rśine of the altitude (for each planet) is to be calculated from the (planet's) own ascensional difference, etc., as taught in connection with the Moon's rising.

In the case of conjunction of the planets (i.e., occultation of one planet by another), the lambana and nati are prescribed to be found out (by proportion) from the (planets') own "dividing numbers". The remaining processes such as the calculation of the sthityardha (i.e., the semi-duration of occultation) are the same as in the case of a (solar) eclipse.

Concluding stanzas:

61-62. The predictions of those (astronomers) whose minds are purified by day to day practice and who have acquired by the grace of the teacher the eye of true conception of the astronomical science, (always) agree with the planetary phenomena and do not go astray as the pure thoughts (desires) of a lovely and devoted wife (do not go astray).
CHAPTER VII

ASTRONOMICAL CONSTANTS

Revolutions performed by the planets around the Earth in a period of 43,20,000 solar years (called a yuga):

1-5. The revolution-number (bhagaña) of the Sun is 43,20,000; of the Moon, 5,77,53,336; of Saturn, 1,46,564; of Jupiter, 3,64,224; of Mars, 22,96,824; of Mercury and Venus and of the śighrocca of the other planets, the same as that of the Sun; of the Moon's apogee, 4,88,219; of (the śighrocca of) Mercury, 1,79,37,020; of (the śighrocca of) Venus, 70,22,388; and of the Moon's ascending node, 2,32,226.

Intercalary months, omitted lunar days, and civil days in a yuga:

6-8. The number of intercalary months (in a yuga) is 15,93,336. For the determination of the number of intercalary months elapsed, (this is the multiplier): the divisor is twelve times the number of solar years in a yuga (i.e., 5,18,40,000). The number of omitted lunar days (in a yuga) is 2,50,82,580. (For finding the number of omitted lunar days elapsed, this is the multiplier): the divisor is 1,60,30,00,080 (which is the number of lunar days in a yuga). The number of civil days in a yuga is stated to be 1,57,79,17,500.

Intercalary months in a yuga

\[ \text{Intercalary months in a yuga} = (\text{lunar months in a yuga}) - (\text{solar months in a yuga}) \]
\[ = \{ (\text{revolution-number of the Moon}) - (\text{revolution-number of the Sun}) \} - 12 \times (\text{revolution-number of the Sun}) \]
\[ = (\text{revolution-number of the Moon}) - 13 \times (\text{revolution-number of the Sun}) \]
\[ = 15,93,336. \]

Omitted lunar days in a yuga

\[ \text{Omitted lunar days in a yuga} = (\text{lunar days in a yuga}) - (\text{civil days in a yuga}) \]
\[ = 2,50,82,580. \]
Inclinations of the orbits of the planets to the ecliptic:

9. The degrees of the greatest celestial latitudes of Mercury, Venus, and Saturn are each 2; of Jupiter, 1; and of Mars, 1⅓.¹

Longitudes of the ascending nodes of the planets and a rule for finding the celestial latitude of a planet:

10. The degrees of the longitudes of the ascending nodes (of the same planets) are 20, 60, 100, 80, and 40 respectively.² The celestial latitude, north or south, (of a planet) should be given out after calculation from the longitude of the planet minus the longitude of its ascending node.

Longitudes of the apogees of the planets and the method for finding the manda and sighra anomalies:

11-12. The degrees of the longitudes of the apogees (of the same planets) are respectively 210, 90, 236, 180, and 118. Of the Sun they are to be known as 78.³

(In order to get the manda anomaly) subtract the longitude of the apogee (of the planet) from the longitude of the planet; and (in order to obtain the sighra anomaly) always subtract the longitude of the planet from the longitude of the sighrocca (of the planet).

Manda and sighra epicycles of the planets, and Rsine-differences corresponding to the twenty-four elements of a quadrant;

13-16. In (the beginnings of) the odd quadrants the manda and sighra epicycles (of Mercury, Venus, Saturn, Jupiter, and Mars) are 7, 4, 9, 7, 14 and 31, 59, 9, 16, 53 (respectively); and in (the beginnings of) the even quadrants they are stated to be 5, 2, 13, 8, 18 and 29, 57, 8, 15, 51 (respectively). Of the Sun and the Moon, the epicycles are 3 and 7 (respectively).

¹ The same values are found in A, i, 8 and SidiVT, I, x. 5(i).
² The same longitudes are given in A, i, 9(i) and SidiVT, I, x. 5(ii).
³ These longitudes are the same as found in A, i, 9(ii) and SidiVT, I, ii. 28(i), 9(iv).
The Rsine-differences (corresponding to the twenty-four elements of a quadrant) are 225 (makhi), etc. (as stated by Āryabhaṭa I).²

The dimensions of the epicycles have been stated after dividing them by 4½. They are the same as given by Āryabhaṭa I. In fact all the astronomical constants stated in the above stanzas are the same as found in the Āryabhaṭīya.

It must be pointed out that, according to Bhāskara I, the manda and ṣīghra epicycles stated above from the Āryabhaṭīya of Āryabhaṭa I, correspond to the beginnings of the respective quadrants as is evident from the rule stated in MBh, iv. 38-39(i) and LBh, ii. 31-32 and explained in Bhāskara I’s commentary on Ā, iii. 22. Govinda Svāmī, however, is of opinion that the ṣīghra epicycles stated by Āryabhaṭa I correspond to the beginnings of the respective quadrants, but the manda epicycles stated by Āryabhaṭa I, correspond to the endings of the respective quadrants.³ Consequently, he has replaced the rule referred to above by another rule which has been quoted by Udaya-divākara in his commentary on LBh, ii. 31-32. This controversy is due to the fact that Āryabhaṭa I himself does not say whether the epicycles given by him correspond to the beginnings or endings of the quadrants.

A rule for finding the bāhuphala and koṭiphala, etc., without the use of the Rsine-difference table:

17-19. (Now) I briefly state the rule (for finding the bhujaphala and koṭiphala etc.) without making use of the Rsine-differences, 225, etc.

Subtract the degrees of the bhujā (or koṭi) from the degrees of half a circle (i.e., 180°). Then multiply the remainder by the degrees of the bhujā (or koṭi) and put down the result at two places. At one place subtract the result from 40500. By one-fourth of the remainder (thus obtained) divide the result

² For the table of Rsine-differences referred to here, see supra, p. 108.
³ See Govinda Svāmī’s comm. on MBh, iv. 38-39(i).
at the other place as multiplied by the \textit{antyaphala} (i.e., the epicyclic radius)\(^1\). Thus is obtained the entire \textit{bākuphala} (or \textit{kotiphala}) for the Sun, Moon, or the star-planets. So also are obtained the direct and inverse Rsines.\(^2\)

This rule is based on the formula:

\[
\sin \theta = \frac{4(180 - \theta)\theta}{40500 - (180 - \theta)\theta},
\]

where \(\theta\) is in degrees.

The following is a \textit{rationale} of this approximate formula: In Fig. 24, let CA be the diameter of a circle of radius \(R\), where arc AB is equal to \(\theta\) degrees and BD = \(R\sin \theta\). Then

Area ABC = \(\frac{1}{2}\) AB. BC.
Also area ABC = \(\frac{1}{2}\) AC. BD.

Therefore,

\[
\frac{1}{BD} = \frac{AC}{AB. BC},
\]

so that

\[
\frac{1}{BD} = \frac{AC}{(\text{arc AB}) \times (\text{arc BC})}.
\]

Let

\[
\frac{1}{BD} = \frac{x \cdot AC}{(\text{arc AB}) \times (\text{arc BC})} + y
\]

\[
= \frac{2xR}{\theta (180 - \theta)} + y,
\]

so that \(R\sin \theta = \frac{\theta (180 - \theta)}{2xR + \theta (180 - \theta)y} \quad \text{(1)}\)

Putting \(\theta = 30^\circ\),

\[
\frac{1}{4} R = \frac{30 \times 150}{2xR + 30 \times 150 y},
\]

i.e., \(2xR + 4500 y = \frac{9000}{R} \quad \text{(2)}\),

\(^1\) इद्दोष्यन्तः क्षणागारे परम्पराग्ना। BrSpSi, xiv. 24(ii).

\(^2\) Cf. BrSpSi, xiv. 23-24; SiŚe, iii. 17.
Putting $\theta=90^\circ$,

$$2xR + 8100y = \frac{8100}{R}.$$  \hspace{1cm} (3)

From (2) and (3),

$$y = -\frac{1}{4R},$$

and $$2xR = \frac{40500}{4R}.$$

Therefore, from (1)

$$R\sin\theta = \frac{4\theta(180-\theta)R}{40500-\theta(180-\theta)}.$$

The same result may also be derived as follows:

Let

$$\sin \lambda = \frac{a+b\lambda + c\lambda^2}{A+B\lambda + C\lambda^2},$$

where $\lambda$ is in radians and corresponds to $\theta$ degrees.

Putting $\lambda=0$, $a=0$.

Putting $\lambda=\pi$, $b+\pi c=0$. Therefore, $c=-\frac{b}{\pi}$.

Thus

$$\sin \lambda = \frac{b\lambda(\pi-\lambda)/\pi}{A+B\lambda + C\lambda^2}.$$

Since $\sin \lambda = \sin(\pi-\lambda)$, therefore

$$\frac{b\lambda(\pi-\lambda)/\pi}{A+B\lambda + C\lambda^2} = \frac{b\lambda(\pi-\lambda)/\pi}{A+B(\pi-\lambda) + C(\pi-\lambda)^2}.$$

or

$$A+B\lambda + C\lambda^2 = A+B(\pi-\lambda) + C(\pi-\lambda)^2,$$

or

$$B(2\lambda-\pi) = C\pi(\pi-2\lambda),$$

giving

$$C = -\frac{B}{\pi}.$$

Therefore,

$$\sin \lambda = \frac{b\lambda (\pi-\lambda)}{A\pi + B\lambda(\pi-\lambda)}.$$

Putting in this $\lambda=\frac{b}{\pi}$,

$$A\pi + B\frac{1}{\pi}(\pi-\frac{1}{\pi}) = 2b, \frac{1}{\pi}(\pi-\frac{1}{\pi}),$$

or

$$A\pi + \frac{5\pi^2 B}{36} = \frac{10\pi^2 b}{36}.$$  \hspace{1cm} (4)
Also putting $\lambda = \frac{1}{12} \pi$,
\[ A\pi + B\frac{3}{4}\pi(\pi - \frac{1}{4}\pi) = b\frac{1}{2}\pi(\pi - \frac{1}{4}\pi), \]
or $A\pi + \frac{3}{4}\pi^2 B = \frac{1}{2}\pi^2 b$. \hfill (5)

From (4) and (5),
\[ B = -\frac{1}{2}b, \]
and $A = \frac{5\pi b}{16}$.

Therefore,
\[ \sin \lambda = \frac{16\lambda (\pi - \lambda)}{5\pi^2 - 4\lambda(\pi - \lambda)}, \]
where $\lambda = \pi \theta/180$.

The length of the so-called circle of the sky and the rule for deriving the length of the orbit of a planet:

20. Multiply the revolution-number of the Moon by 216000: then is obtained the length of the circle of the sky (in terms of *yojana*). When the circle of the sky is divided by the revolution-number of any given planet, the quotient denotes the length of the circular orbit of that planet.

Thus we get

(1) length of the circle of the sky $= 1,24,74,72,05,76,000$ *yojana*,

(2) length of the Sun’s orbit $= 28,87,666 \frac{4}{5}$ *yojana*,

(3) length of the Moon’s orbit $= 2,16,000$ *yojana*,

(4) length of Mars’ orbit $= 54,31,291 \frac{132027}{287103}$ *yojana*,

(5) length of Mercury’s orbit $= 6,95,473 \frac{373277}{896851}$ *yojana*,

(6) length of Jupiter’s orbit $= 3,42,50,133 \frac{699}{1897}$ *yojana*,

(7) length of Venus’s orbit $= 17,76,421 \frac{255221}{585199}$ *yojana*,

(8) length of Saturn’s orbit $= 8,51,14,493 \frac{5987}{36641}$ *yojana*.

Midnight day-reckoning of *Aryabhaṭa* I:

21. The astronomical processes which have been set forth above come under the sunrise day-reckoning. In the midnight
day-reckoning too, all this is found to occur: the difference that exists is being stated (below).

The next fourteen stanzas relate to the midnight day-reckoning of Āryabhaṭa I.

Civil days and omitted lunar days in a yuga and revolution-numbers of Mercury and Jupiter:

22. (To get the corresponding elements of the midnight day-reckoning) add 300 to the number of civil days (in a yuga) and subtract the same (number) from the number of omitted lunar days (in a yuga); and from the revolution-numbers of (the śīghrocca' of) Mercury and Jupiter subtract 20 and 4 respectively.

Thus according to the midnight day-reckoning,

- civil days in a yuga = 1,57,79,17,800,
- omitted lunar days in a yuga = 2,50,82,280,
- revolution-number of the śīghrocca of Mercury = 1,79,37,000,
- revolution-number of Jupiter = 3,64,220.

Diameters of the Earth, the Sun, and the Moon:

23. (In the midnight day-reckoning) the diameter of the Earth is (stated to be) 1600 yojanas; of the Sun, 6480 (yojanas); and of the Moon, 480 (yojanas).

Mean distances of the Sun and the Moon:

24. The (mean) distance of the Sun is stated to be 689358 (yojanas); and of the Moon, 51566 (yojanas).

Longitudes of the apogees of the planets:

25. 160, 80, 240, 110, and 220 are in degrees the longitudes of the apogees of Jupiter, Venus, Saturn, Mars, and Mercury respectively.

---

1 Cf. KK (Sengupta's edition), ii. 6(i).
Manda and śighra epicycles of the planets:

26-28(i). The manda epicycles (of the same planets) are 32, 14, 60, 70, and 28 (degrees) respectively; and the śighra epicycles are 72, 260, 40, 234, and 132 (degrees) respectively. The Sun’s apogee and epicycle are the same as those of Venus (i.e., 80° and 14° respectively). The Moon’s epicycle in the midnight day-reckoning is stated to be 31 (degrees).

Positions of the so called manda and śighra pātas of the planets:

28(ii)-31(i). (The following directions for) the degrees of the (manda and śighra) pātas of the planets as devised (under the midnight day-reckoning) should be noted carefully by learned scholars.

Add 180° to the longitudes of the mandoceas (apogees) and śighroceas of Mercury and Venus, and subtract 3 signs from the mandoceas (apogees) and śighroceas of the remaining planets. Then are obtained the longitudes of the manda and śighra pātas of the planets. (Also) add 2 degrees to the longitudes of the manda pātas and śighroceas of Venus, Saturn, and Jupiter; and 1 ½ degrees to those of Mars and Mercury. (It should be noted that) the śighra pātas have been stated for all the planets excepting Mercury. (Mercury does not have a śighra pāta).¹

That is to say, the longitudes of the manda-pātas of Mars, Mercury, Jupiter, Venus, and Saturn are 21°-5, 41°-5, 72°, 262°, and 152° respectively; and the longitudes of the śighra-pātas of Mars, Jupiter, Venus, and Saturn are (śighrocca — 88°-5), (śighrocca — 88°), (śighrocca + 182°) and (śighrocca — 88°) respectively.

¹ This passage represents rather old ideas of Hindu astronomy. The conception of manda and śighra pātas does not occur in any other work. Our translation agrees with the interpretations given in the various commentaries. The translation given by P. C. Sengupta in the introduction to his Khaṇḍa-khādyaka is wrong.
A rule for finding the celestial latitude of a planet:

31(ii)-33. (From the longitude of a planet severally) subtract the longitudes of its (manda and śīghra) pūtaś, and therefrom calculate (as usual) the corresponding celestial latitudes of that planet. Add them or take their difference according as they are of like or unlike directions. Then is obtained the true celestial latitude of that particular planet. The true celestial latitude of any other planet is also obtained in the same way. The remaining (astronomical) determinations are the same as stated before. This all is in brief the difference of the other tantra (embodying the midnight day-reckoning of Āryabhata I).

A rule for finding the longitude of the true-mean planet according to the midnight day-reckoning:

34. Apply half the śīghraphala and (then) half the mandaphala to the longitude of the planet’s own mandocca (reversely). From the resulting longitude of the planet’s mandocca calculate (the mandaphala and apply it to the the mean longitude of the planet: the resulting longitude of planet is stated to be) the true-mean longitude of the planet. This is stated to be another difference (of the midnight day-reckoning).¹

Length of the circle of the sky and derivation of the lengths of the orbits of the planets:

35. Multiply the revolutions of the Moon (in a yuga) by 32,40,000 and then discard the zero in the unit’s place: (this is the length of the circle of the sky in terms of yojanas). (Severally) divide that by the revolutions of the planets (in a yuga): thus are obtained the lengths of the orbits of the respective planets in terms of yojanas.

From stanzas 20 and 35 it is evident that one yojana of the sunrise day-reckoning is one and a half times that of the midnight day-reckoning.

¹ This rule is the same as found in PSI, xvii. 4-9; SūSī, ii, 44; MSī, iii. 28; and SīTV, ii. 247.
CHAPTER VIII

EXAMPLES

(Solved Examples)

To find the true lunar day (tithi) and the ghatīs elapsed at sunrise since the beginning of the current lunar day without the knowledge of the true longitudes of the Sun and Moon:

1-4. Multiply the ahhargaṇa by the number of lunar years\(^1\) (in a yuga) and divide by the number of civil days\(^2\) (in a yuga). Then are obtained the mean lunar years, etc. (corresponding to the ahhargaṇa). Also multiply the ahhargaṇa by the number of intercalary lunar years\(^3\) (in a yuga) and divide by the number of civil days\(^2\) (in a yuga). (Thus are obtained the mean intercalary years, etc., corresponding to the ahhargaṇa). The difference between the two denotes the (mean) solar years, etc. (i.e., years, months, days, and ghatīs) (corresponding to the ahhargaṇa).

The solar years are not required (so they are to be omitted). From the remaining quantity (in months, days, and ghatīs) subtract two months and eighteen days. Then (treating the months, days, etc., of the remainder thus obtained as the signs, degrees, etc., of the Sun’s mean anomaly) calculate the (Sun’s) equation of the centre.

Divide the (corresponding) solar time by 12 and apply that to the (mean) lunar days (and ghatīs) (obtained from the ahhargaṇa) contrarily (i.e., add when the Sun’s equation of the centre is subtractive and subtract when the Sun’s equation of the centre is additive). Also apply one-twelfth of the time corres-

---

\(^1\) i.e., 44,52,778.
\(^2\) i.e., 1,57,79,17,500.
\(^3\) i.e., 1,32,778.
ponding to the Moon’s equation of the centre\(^1\) to the resulting lunar days (and *ghaṭīs*) in the same way as it is applied to the Moon’s longitude.

(The lunar days thus obtained are the true lunar days which have elapsed at sunrise since the beginning of the current month). The *ghaṭīs* obtained above denote the elapsed portion of the current lunar day in terms of *ghaṭīs*. Multiply those *ghaṭīs* by 60 and divide by one-twelfth of the difference between the true daily motions of the Sun and Moon, in degrees: the quotient denotes the true time in *ghaṭīs* (which has elapsed at sunrise since the beginning of the current lunar day).\(^2\)

Let the mean lunar years, etc., elapsed at sunrise be \(a\) years, \(b\) months, \(c\) days, and \(d\) *ghaṭīs*; and let the mean intercalary years, etc., elapsed at sunrise be \(a'\) years, \(b'\) months, \(c'\) days, and \(d'\) *ghaṭīs*.

Then the mean solar years, etc., elapsed at sunrise are \((a-a')\) years, \((b-b')\) months, \((c-c')\) days, and \((d-d')\) *ghaṭīs*.

The mean longitude of the Sun is therefore equal to \((a-a')\) revolutions, \((b-b')\) signs, \((c-c')\) degrees, and \((d-d')\) minutes. The longitude of the Sun’s apogee being 2°18’, the Sun’s mean anomaly is equal to \((b-b')\) signs, \((c-c'-2)\) degrees, and \((d-d'-18)\) minutes.

Suppose that the Sun’s equation of the centre derived from the above Sun’s mean anomaly is \(m\) minutes. Then we subtract \(m/12\) *ghaṭīs* from or add the same amount to \(c\) days and \(d\) *ghaṭīs* obtained above, according as the Sun’s equation of the centre is additive or subtractive. Thus we get \(c\) days and \((d=m/12)\) *ghaṭīs*.

\(^1\) To obtain the Moon’s equation of the centre, the mean longitude of the Moon may be obtained as follows: Multiply the mean lunar days, etc., (corresponding to the *ahargana*) by 12, convert the resulting days etc. into months, etc., and add to them the mean solar months, etc., (corresponding to the *ahargana*); treat the months, etc., thus obtained as the signs, etc., of the mean longitude of the Moon.

\(^2\) A similar rule occurs in *BrSpSi*, xiii. 23-25 and *SiŚe*, iii. 72-74.
Also suppose that the Moon’s equation of the centre is \( n \) minutes. Then we add \( n/12 \) ghaṭīs to or subtract the same from \( c \) days and \((d \mp m/12)\) ghaṭīs. Thus we obtain

\[
c \text{ days, } (d \mp m/12 \pm n/12) \text{ ghaṭīs.}
\]

\( c \) days in this result shows that \( c \) complete true lunar days have elapsed at sunrise; and \((d \mp m/12 \pm n/12)\) ghaṭīs shows that part of the current lunar day amounting to so many ghaṭīs has also elapsed at sunrise.

Multiplying \((d \mp m/12 \pm n/12)\) by \(60\) and dividing the product by \(1/12\) of the degrees of difference between the true daily motions of the Sun and Moon are obtained the ghaṭīs elapsed at sunrise since the beginning of the current lunar day.

The following is the rationale of the above rule:

True lunar day (tithi)

\[
= (\text{true longitude of the Moon—true longitude of the Sun})/12.
\]

\[
= ((\text{mean longitude of the Moon } \pm \text{Moon’s equation of the centre})-(\text{mean longitude of the Sun } \pm \text{Sun’s equation of the centre}))/12.
\]

\[
= ((\text{mean longitude of the Moon } - \text{mean longitude of the Sun})
\mp (\text{Sun’s equation of the centre}) \pm (\text{Moon’s equation of the centre}))/12.
\]

\[
= \frac{ahargaṇa \times (\text{Moon’s rev.-number—Sun’s rev.-number})^1}{\text{civil days in a yuga} \times 12}
\]

\[
= (\text{Sun’s equation of the centre})/12
\pm (\text{Moon’s equation of the centre})/12
\]

\[
= \frac{ahargaṇa \times (\text{lunar years in a yuga})}{\text{civil days in a yuga}}
\]

\[
= (\text{Sun’s equation of the centre})/12
\pm (\text{Moon’s equation of the centre})/12
\]

\[
= \text{mean lunar years, etc., elapsed at sunrise}
\]

\[
= (\text{Sun’s equation of the centre})/12
\pm (\text{Moon’s equation of the centre})/12.
\]

\[^1\text{Rev.-number denotes revolution-number,}\]
= mean lunar days and $ghaft$s elapsed at sunrise
\[ \equiv (\text{Sun's equation of the centre})/12 \]
\[ \equiv (\text{Moon's equation of the centre})/12, \]

where the signs are chosen appropriately. Lunar months and years are discarded as they are not required.

To obtain the Sun's mean longitude from the Sun's true longitude derived from the midday shadow of the gnomon:

5. Subtract the longitude of the Sun's apogee from the Sun's true longitude derived from the midday shadow (of the gnomon) and (then treating the remainder as the Sun's mean anomaly) calculate the Sun's equation of the centre. Apply that (equation of the centre) to the Sun's true longitude contrarily to the usual law for its subtraction and addition. (Treating this result as the mean longitude of the Sun, calculate the Sun's equation of the centre afresh and apply that to the Sun's true longitude as before.) Repeat the same process again and again (until two successive results agree to minutes). Thus is obtained the mean longitude of the Sun.

The method used here is evidently the method of successive approximations.

To find the arc corresponding to a given Rsine:

6. From the given Rsine subtract in serial order (as many tabulated Rsine-differences as possible): multiply the number of the Rsine-differences subtracted by 225. Then multiply the residue (of the given Rsine) by 225 and divide by the current Rsine-difference. Add this result to the previous one. Thus is obtained the arc (corresponding to the given Rsine in terms of minutes).

---

1 This rule occurs also in $BrSpSi$, xiv. 28; iii. 61-62; $SiSl$, I, ii. 45.
2 i.e., the tabulated Rsine-difference which is next to those subtracted.
3 This rule is found also in $SuSt$, ii. 33; $BrSpSi$, ii. 11; $SIDt$, I, ii. 13; $SiSe$, iii. 16; $SiSt$, I, ii. 11(ii)-12(i).
Six examples on the shadow of the gnomon:

7. The latitude (of a place) is one and a half degrees minus eight minutes (i.e., $1^\circ 22'$); and the midday shadow of the gnomon of 12 $\text{angulas}$ on level ground is 5 $\text{angulas}$. Give out the sun’s longitude at noon on that day.\(^1\)

8. Quickly say the longitude of the meridian Sun for the place where the latitude is stated to be 8 degrees minus 16 minutes (i.e., 7° 44') and the midday shadow of the gnomon, 3 and a half (angulas).

9. Quickly say the true longitudes of the Sun for the places where the latitudes are stated to be 25 and 30 degrees respectively and the lengths of the midday shadows (of the gnomon) are equal to the gnomon (itself).

10. Say what is the longitude of the Sun at the place where the latitude is 15 degrees and the prime vertical shadow of (the gnomon due to) the Sun, one and a half $\text{angulas}$ together with one-fifth of an $\text{angula}$ (i.e., 17/10 $\text{angulas}$).\(^2\)

11. The prime vertical shadow (of the gnomon) is 37 $\text{angulas}$ and the equinoctial midday shadow is 30 $\text{angulas}$. Say the longitude of the universal lamp, the Sun, for its position on the prime vertical.

12. The east-west shadow (of the gnomon) is seen on level ground to be 16 (angulas). The latitude of the place is seven and a half degrees. Say what is the Sun’s longitude there.

\(^1\) The examples set in this and the next two stanzas are based on the rules stated before in chapter III, stanzas 5 and 13-15.

\(^2\) The examples set in this and the next two stanzas are based on the rules given before in chapter III, stanzas 5 and 41.
Eleven examples on the pulveriser (kutākāra):

13. The signs, etc., up to the thirds of the Sun’s (mean) longitude have all been carried away by the strong wind; the residue of thirds is known to me to be 101. Tell (me) the Sun’s (mean) longitude and also the ahargana.\(^1\)

14. The minutes together with the signs and degrees of the Moon’s (mean) longitude have been destroyed being rubbed out by the hands of a child; twenty-five seconds are seen to remain (undestroyed). Calculate from them, O you of noble descent, the ahargana and the (mean) longitude of the Moon.

The following is the solution of this example:

\[
\text{Revolution-number of the Moon reduced to minutes} = 68167872 \\
\text{civil days in a yuga} = 86225
\]

Multiplying 25 by 86225 and dividing the product by 60, the quotient is 35927. This is the residue of the minutes (Kalāśeṣa).\(^2\) We have, therefore, to solve the pulveriser

\[
\frac{68167872 x - 35927}{86225} = y,
\]

where \(x\) denotes the required ahargana and \(y\) the Moon’s mean longitude in terms of minutes.

By the usual process\(^3\), we get

\[
x = 70091,
\]

\[
y = 55412633'.
\]

Hence the required ahargana = 70091 days, and the Moon’s mean longitude = 4 signs 23° 53’ 25’’.

15. The signs and degrees (of the mean longitude of Mars) have been carried away by the hurricane; the residue of the

\(^1\) Answer: Ahargana = 106141; Sun’s mean longitude = 3 signs 32° 52’23’’11’’. For complete solution see supra, pp. 35-36.

\(^2\) Vide supra, chapter I, stanza 46(ii), p. 33.

\(^3\) Vide supra, chapter I, stanzas 42-44, p. 30.
degrees is 73. Say what is the (mean) longitude of Mars and also what is the $ahargana$.

The following is the solution of this example:

\[
\frac{{\text{Revolution-number of Mars reduced to degrees}}}{{\text{civil days in a yuga}}} = \frac{13780944}{26298625} = 0.5255
\]

The pulveriser to be solved is therefore

\[
\frac{13780944x - 73}{26298625} = y,
\]

where $x$ denotes the required $ahargana$ and $y$ the mean longitude of Mars in terms of degrees.

Solving the pulveriser by the usual process, we get

\[
x = 17420617
\]

\[
y = 9128711.
\]

Hence the required $ahargana = 17420617$ days, and the mean longitude of Mars $= 9128711^\circ$, i.e., 25357 revs., 6 signs, 11 degrees.

16. The (mean) longitude of Mercury is 3 signs, 15 degrees, and 5 minutes. Considering this give out the days elapsed (i.e., the $ahargana$) and also the revolutions performed by him.

The following is the solution of this example:

Longitude of Mercury $= 3$ signs $15^\circ 5'$

\[
= 6305'.
\]

Now

\[
\frac{{\text{revolution-number of Mercury}}}{{\text{civil days in a yuga}}} = \frac{896851}{78895875}
\]

Therefore multiplying 6305 by 78895875 and then dividing the product by 21600, we get 23029559 as the quotient. This is the residue of the revolutions. Thus we have to solve the pulveriser

\[
\frac{896851x - 23029559}{78895875} = y,
\]

where $x$ denotes the $ahargana$ and $y$ the required revolutions.
By the usual method, we get \( x = 74350409 \) and \( y = 845180 \).

17. The signs, degrees, and minutes of the (mean) longitude of Jupiter have been destroyed by a mischievous child; nine seconds are seen to remain (undisturbed). Say therefrom the \textit{ahargaṇa} and the mean longitude of Jupiter.

The following is the solution of this example:

\[
\frac{\text{Revolution-number of Jupiter reduced to minutes}}{\text{civil days in a yuga}} = \frac{26224128}{5259725}
\]

Multiplying 9 by 5259725 and dividing the product by 60, we obtain 788958 as the quotient. This is the residue of the minutes. Then we have to solve the pulveriser

\[
\frac{26224128x - 788958}{5259725} = y,
\]

where \( x \) denotes the \textit{ahargaṇa} and \( y \) the longitude of Jupiter in terms of minutes.

Solving the pulveriser, we get \( x = 2269811, y = 11316906', \ i.e., \ 523 \ revs., 11 \ signs, 5 \ degrees, 6 \ minutes. \) The required \textit{ahargaṇa} is therefore 2269811 days, and the mean longitude of Jupiter is 11 signs 5° 6' 9''.

18. The revolutions, etc., up to the minutes of the (mean) longitude of Venus are destroyed; 10 seconds are seen to remain intact. Of Saturn, 17 seconds are found to remain intact. Quickly say (the mean longitudes of) them and also the \textit{ahargaṇa} (in the two cases).

The following is the solution of this example:

\[
\frac{\text{Revolution-number of Venus reduced to minutes}}{\text{civil days in a yuga}} = \frac{505611936}{5259725}
\]

Multiplying 10 by 5259725 and dividing the product by 60, the quotient is 876620: this is the residue of the minutes. The resulting pulveriser is

\[
\frac{505611936x - 876620}{5259725} = y,
\]

where \( x \) is the \textit{ahargaṇa} and \( y \) the corresponding longitude of Venus in
minutes. Solving this pulveriser, we get \( x = 4081170, y = 392318660 \). Hence the \( ahargaṇa = 4081170 \) days, and the corresponding mean longitude of Venus = 10 signs 24° 20' 10''.

Again

\[
\frac{\text{revolution-number of Saturn reduced to minutes}}{\text{civil days in a yuga}} = \frac{10552608}{5259725}
\]

Multiplying 17 by 5259725 and dividing the product by 60, the quotient is 1490255: this is the residue of the minutes. The resulting pulveriser is

\[
\frac{10552608 \times 1490255}{5259725} = y,
\]

where \( x \) denotes the \( ahargaṇa \) and \( y \) the mean longitude of Saturn in minutes. Solving this pulveriser, we get \( x = 3308510, y = 6637877 \). Hence the required \( ahargaṇa = 3308510 \), and the mean longitude of Saturn = 3 signs 21° 17' 17''.

19. The sum of the (mean) longitudes of Mars and the Moon is calculated to be 5 signs, 7 degrees, and 9 minutes. O you, well versed in the \( (Arya)bhaṭa-tantra \), quickly say the \( ahargaṇa \) and also the (mean) longitudes of the Moon and Mars.¹

The following is the solution of this example:

Mean longitude of Mars + mean longitude of the Moon = 5 signs 7° 9'

\[= 9429'.\]

Also

\[
\frac{\text{sum of the revolution-numbers of Mars and the Moon}}{\text{civil days in a yuga}} = \frac{1000836}{26298625}
\]

Multiplying 9429 by 26298625 and dividing the product by 21600, the quotient is 11480080: this is the residue of the revolutions. We have therefore to solve the pulveriser

\[
\frac{1000836 \times 11480080}{26298625} = y,
\]

where \( x \) is the required \( ahargaṇa \). Solving the pulveriser, we get \( x = 5646655 \). From this \( ahargaṇa \) we can easily calculate the mean longitudes of Mars and the Moon.

¹ For Govinda Svāmi’s modification of this example, see supra, chapter I, under stanza 52.
20. The difference between the mean longitudes of Mars and Jupiter is exactly 5 signs. Say what is the number of days elapsed since the beginning of Kaliyuga and what are the (mean) longitudes of Jupiter and Mars.¹

21-22. The Sun and Moon on a Sunday at sunrise are carefully seen by me in (the sign) Libra. The degrees of their (mean) longitudes are 12 and 2 respectively; the minutes are 1 and 40 respectively. After how many days will they assume the same longitudes again (at sunrise) on a Thursday, Friday, and Saturday respectively? (It is also given that) the (mean) longitude of the Sun is in excess by 17 seconds (over that given above); whereas from the (mean) longitude of the Moon (given above 18 seconds have to be subtracted.²

That is to say,

the Sun’s longitude = 6 signs, 12 degrees, 1 minute, and 17 seconds;
and the Moon’s longitude = 6 signs, 2 degrees, 39 minutes, and 42 seconds.

Calculation will show that the Sun and Moon assume these longitudes on a Sunday 7500 days after the commencement of Kaliyuga.

The problem now is to find out the ahargaṇa when the Sun and Moon again assume the same longitudes at sunrise on a Thursday, Friday, and Saturday respectively. This is done as follows:

(i) Ahargaṇa for Thursday. Let the corresponding ahargaṇa be 7500 + A. Obviously, in A days the Sun and Moon will describe complete revolutions. Also since Thursday is four days in advance of Sunday, therefore A—4 will be perfectly divisible by seven. In other words,

\[
\frac{576A}{210389} \quad \frac{78898A}{2155625} \quad \text{and} \quad \frac{A-4}{7}
\]

will be whole numbers. If we assume A = 131493125X,³ the first two

¹ This example has been solved in chapter I under stanza 52. See supra, p. 44.
² Bhāskara I’s example, occurring in his comm. on A, ii. 32-33.
³ This number is the L.C.M. of 210389 and 2155625.
fractions will obviously be whole numbers, and we have only to make

\[
\frac{131493125X-4}{7} = Y,
\]

or

\[
\frac{X-4}{7} = Z, \text{ where } Y = 18784732X+Z.
\]

Solving this equation, we find that \(X = 4\) makes \(131493125X-4)/7\) a whole number. Therefore, the required \(ahargaña\)

\[
= 7500+\frac{A}{7}
\]

\[
= 7500+131493125X
\]

\[
= 7500+131493125\times 4
\]

\[
= 525980000 \text{ days.}
\]

(ii) \(Ahargaña\) for Friday. In this case, the required \(ahargaña\) is obviously equal to \(7500+131493125\times 5\), i.e., 657473125 days.

(iii) \(Ahargaña\) for Saturday. In this case, the required \(ahargaña = 7500+131493125\times 6 = 788966250 \text{ days.}\)

23. The revolutions, etc., of the Sun’s (mean) longitude, calculated from an \(ahargaña\) plus a few \(nādis\) elapsed, have now been destroyed by the wind; 71 minutes are seen by me to remain intact. Say the \(ahargaña\), the sun’s (mean) longitude, and the correct value of the \(nādis\) (used in the calculation).\(^1\)

24-24*. Some number of days is (severally) divided by the (abraded) civil days for the Sun and for Mars. The (resulting) quotients are unknown to me; the residues, too, are not seen by me. The quotients obtained by multiplying those residues by the respective (abraded) revolution-numbers and then dividing (the products) by the respective (abraded) civil days are also blown away by the wind. The remainders of the two (divisions) now exist. The remainder for the Sun is 38472; that for Mars, 77180625. From these remainders severally

\(^1\) This example has been solved in Chapter I under stanza 49. See supra, p. 40.
calculate, 3 mathematician, the *ahargaṇas* for the Sun and Mars and also the *ahargaṇa* conforming to the two residues and state them in proper order.¹

One example on the determination of the latitude:

25. The Sun being at the end of (the sign) Gemini, the length of the night is 21 *ghatiś*. Calculate and give out the latitude and also the colatitude of the place.²

Authorship and appreciation of the work:

26. This *Āryabhaṭa-karma-nibandha* ("a compendium of astronomical processes based on the teachings of Āryabhata I"), which has clear expressions and simple methods (of calculation) and which can be comprehended even by those with lesser intellect, is written by Bhāskara after full deliberation.

27. Whatever occurs in this work regarding the projection and calculation of solar eclipses (etcetera), which are dealt with by giving numerous rules with clear meaning, also finds place elsewhere; and what does not find place here does not occur anywhere else.

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¹ This example has been solved in Chapter I under stanza 52. See *supra*, p. 45-46.

² Assuming the obliquity of the ecliptic to be 23°30′, the required latitude comes out to be 61°45′ approx.
QUOTATIONS

from the Mahā-Bhāskarīya in Later Works

Passages from the Mahā-Bhāskarīya occur as quotations in the following commentaries:

(1) Śaṅkaranārāyaṇa’s commentary (869 A. D.) on the Laghu-Bhāskarīya.
(2) Udayadivākara’s commentary (1073 A. D.) on the Laghu-Bhāskarīya.
(3) Sūryadeva’s commentaries on the Āryabhatīya and the Laghu-mānasā.
(4) Makkibhaṭṭa’s commentary (1377 A. D.) on the Siddhānta-śekhara.
(5) Parameśvara’s commentary (1408 A. D.) on the Laghu-Bhāskarīya.
(6) Nīlakaṇṭha’s commentary (c. 1500 A. D.) on the Āryabhatīya.
(7) Govinda Somayājī’s commentary, entitled Daśādhyāyi, on the Brhajjñata of Varāhamihira.
(8) Viṣṇu Śarmā’s commentary (c. 1363) on the Vidyā-mādhava-vīya.

Below we refer to these passages and to the places where they occur as quotations.

1. Passages quoted by Śaṅkaranārāyaṇa.

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2. Passages quoted by Udayadivākara.

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<td>MBh, ii. 2(ii)</td>
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<td>MBh, iii. 26</td>
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<td>MBh, iv. 4(ii)</td>
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<td>MBh, iv. 18</td>
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<td>MBh, v. 12(i)</td>
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<td>MBh, v. 33</td>
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<td>MBh, v. 43(ii)</td>
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<td>MBh, vi. 56-58</td>
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<td>MBh, vii. 20(i)</td>
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3. Passages quoted by Sūryadeva.

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<td>MBh, vii. 23(iv)</td>
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4. Passages quoted by Makkibhaṭṭa.

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5. Passages quoted by Parameśvara.

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<td>MBh, vii. 35</td>
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7. Passages quoted in the Daśādhyāyi.\(^1\)
   Passage quoted: MBh, iii. 9.
   Quoted under: BJ, i. 19.

8. Passage quoted by Viṣṇu Śarmā.
   Passage quoted: MBh, vii, 20 (ii).
   Quoted under: ViMā, i. 19.

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\(^1\) Viđe Sudhākara Dvivedi, Gaṇaka-taraṅgiṇī, p. 14.
GLOSSARY
of Terms used in the Mahā-Bhāskarīya

Aṁśa (अंश) (1) Part, fraction.
(2) Degree (°).

Aṁśaka (अंशक) Degree.

Aṁśumat (अंशमत) Sun.

Aḵṣa (अक्ष) (1) Latitude. (2) Five.

Aḵṣakarṇa (अक्षकर्ण) The hypotenuse of the equinoctial midday shadow (of the gnomon).

Aḵṣakoti (अक्षकोटि) Colatitude.
Also, sometimes, the R̄sine of colatitude.

Aḵṣagūṇa (अक्षगुण) The R̄sine of latitude.

Aḵṣacāpa (अक्षचाप) The arc of latitude, or simply latitude.

Aḵṣacāpagrama (अक्षचापगम) The R̄sine of latitude.

Aḵṣajīva (अक्षजीव) The R̄sine of latitude.

Aḵṣajyā (अक्षज्या) The R̄sine of latitude.

Aḵṣabhāga (अक्षभाग) The degrees of latitude.

Aḵṣavalana (अक्षवलन) See Valana.

Aḵṣasya valanaṁ (अक्षस्य वलनम्) Aṅgula (अंगुल) Finger-breadth.
A unit of linear measure.

Aṅga (अंग) Six.

Aṅgāraka (अंगारक) Mars.

Aṅgula (अंगुल) Finger-breadth.
ment defined by the breadth of eight barley corns.

Acāla (अचळा) (1) Seven. (2) Fixed. To make acāla in astronomy means to apply the method of successive approximations.

Aja (अज) The sign Aries.

Ativakra (अतिवक्र) A planet is said to be ativakra when it is in the middle of its retrograde motion.

Adri (अद्रि) Seven.

Adhika-māsa (अधिकमास) Intercalary month. The Intercalary months denote the excess of the lunar (synodic) months over the solar months in a certain period. Thus intercalary months in a yuga = lunar months in a yuga — solar months in a yuga.

A true intercalary month is one in which the Sun does not pass from one sign into the next.

Adhikābda (अधिकाब्द) Intercalary year, i.e., a collection of twelve intercalary months. See Adhikamāsa.

Adhikāha (अधिकास) Intercalary day, i.e., intercalary tīthi.

Adhimāsa (अधिमास) Intercalary month. See Adhikamāsa.

Adhimāsaka (अधिमासक) Same as Adhimāsa.

Adhimāsāsena (अधिमाससेन) The residue of the intercalary months.

Adhva (अध्व) The distance of a place from the prime meridian.

Adhvā (अध्व) Same as Adhva.

Adhvāna (अध्वान) Same as Adhva.

Anudīṣ (अनुदीश) Parallel.

Anupāta (अनुपात) Proportion.

Anuloma (अनुलोम) Direct. A planet is said to be anuloma when its motion is direct, i.e., from west to east.

Antyaguna (अन्त्यगुण) See Antyajīva.

Antyajīva (अन्त्यजीव) The current Rsine-difference, i.e., the Rsine-difference corresponding to the elementary arc occupied by a planet. In Hindu trigonometry a quadrant of a circle is divided into 24 equal parts, called elementary arcs.

Antyajīva (अन्त्यजीव) Same as Antyajīva.
Antyaphala (अंत्यफळ) Maximum correction due to mandonca or maximum correction due to śighrocca. The former is equal to the radius of the manda epicycle and the latter is equal to the radius of the śighra epicycle.

Apakrama (अपक्रम) Declination.
Apakramaguna (अपक्रमगुण) The Rsine of declination.
Apakramajyā (अपक्रमज्या) The Rsine of declination.
Apakramadhanu (अपक्रमधनु) The arc of declination, or simply declination.

Apagama (अपगम) Declination.
Apacaya (अपचय) Decrease.
Apama (अपम) Declination.
Apamadhanu (अपमधनु) The arc of declination, i.e., declination.

Apamo gunah (अपमो गुणः) The Rsine of declination.

Apavarta (अपवर्त) The greatest common divisor; abrader.

Abdapa (अब्दप) The lord of the year, i.e., the planet which is the regent of the first day of the year.

Abdhi (अभ्दि) Four.
Abhyāsa (अभ्यास) Multiplication.
Abhra (अभ्र) Zero.
Amṛtajejas (अमृतजेजस्) Moon.
Amṛdadidhiti (अमृतदीधिति) Moon.
Ambara (अम्बर) Zero.

Ambaroruparidhi (अम्बरोरुपरिधि) The word ambara means, according to Hindu astronomers, “that part of the sky which is illuminated by the rays of the Sun.” The word ambaroruparidhi likewise means “the periphery of the illuminated sphere of the sky”.

Ayana (अयन) The northward or southward course of a planet, particularly the Sun. The ayana of a planet is north or south according as the planet lies in the half-orbit beginning with the sāyana sign Capricorn or in that beginning with the sāyana sign Cancer.

Ayuta (अयuta) Ten thousand.
Arka (अर्क) (1) Sun. (2) Twelve.
Arkaputra (अर्कपुत्र) Saturn.
Arkavarsa (अर्कवर्ष) Solar year.
Arkasambhava (अर्कसम्भव) Solar month.
Ardhacaturtha (अर्धचतुर्थ) Three and a half (3½). Literally, four minus half.

Ardhapañcaka (अर्धपञ्चक) or Ardhapañcam (अर्धपञ्चम) Four and a half (4½). Literally, five minus half.

Ardhavistara (अर्धविस्तर) Semi-diameter, radius, or 3438’.

Ardhāstamila (अर्धास्तमिल) Half-set.

Avaṇati (अवनति) (1) Meridian zenith distance. (2) Celestial latitude. (3) Parallax in celestial latitude.

Avaṇatilava (अवनतिलव) The degrees of meridian zenith distance.

Avaṇatilavajīva (अवनतिलवजीव) The Rsin of avaṇatilava.

Avaṇatiliptikā (अवनतिलिप्तिक) Avaṇati in minutes of arc.

Avaṇāma (अवनाम) Zenith-distance.

Avama (अवम) Omitted lunar days or omitted tithis.

Avamarātraśeṣa (अवमरात्राशेष) The residue of the omitted lunar days.

Avamaśeṣa (अवमशेष) The residue of the omitted lunar days.

Avalambaka (अवलम्बक) (1) Plumb. (2) The Rsin of colatitude.

Avalambakagūṇa (अवलम्बकगुण) The Rsin of colatitude.

Avāsęṣa (अवासेष) Remainder.

Aviśīṣṭa (अविशीष्ट) Obtained by applying the method of successive approximations.

Aviśeṣakāraṇa (अविशेषकरण) The distance (lit. hypotenuse) obtained by the method of successive approximations.

Aviśeṣakarma (अविशेषकर्म) The method of successive approximations.

Aviśeṣaṇa (अविशेषण) To perform Aviśeṣakarma.

Aviśeṣatihi (अविशेषतिहि) The tithi (i.e., the time of apparent conjunction of the sun and Moon) obtained by the method of successive approximations.

Aviśeṣanādi (अविशेषनाधि) The nādis obtained by the method of successive approximations.

Aviśeṣavadi (अविशेषवदिः) See Aviśeṣakarma.
Avistisha (अविषीष्ठ) Same as Avistisha.
Avishama (अवियम) Even.
Asvi (अस्वि) Two.
Asvin (अस्विन) Two.
Astiti (अस्तिति) Sixteen.
Asakrt (असक्रत्) Repeatedly, or by using the method of successive approximations.
Asita (असित) (1) Dark. (2) The unilluminated part of the Moon’s disc. (3) Saturn.
Asita-paksa (असितपक्ष) The dark half of a lunar month.
Asu (असु) A unit of time equivalent to 4 seconds.
Asrktanu (अस्क्रतनु) Mars. Mars is called asrktanu (asrk=blood, tanu=body) because it is red in colour.
Asta (अस्त) Setting.
A斯塔kala (अस्तकाल) Time of setting.
Astalagna (अस्तलग्न) The setting point of the ecliptic, i.e. that point of the ecliptic which lies on the western horizon.
Astrasutra (अस्त्रसूत्र) The rising-setting line (udadayasutasutra).
Astodayagrarekhā (अस्तोदयाग्रारेखा) The rising-setting line.
Ahargana (अहर्गण) The number of days elapsed since the beginning of Kaliyuga (or any other epoch).
Aharmana (अहर्मन) The length of day.
Ahoratra (अहोरात्र) A day and night, a zychothemeron.
Ahoratra-vishambha (अहोरात्रविशंभ) Day-radius.
Ahnām ganah (अह्नाम गणः) Same as Ahargana.
Ahnām nicayah (अह्नाम निचयः) Same as Ahargana.
Ākāsā (आकाश) Zero.
Āpya (आप्य) Pūrvāśudha, the twentieth nakṣatra.
Āyama (आयम) Length.
Āra (आर) Mars.
Ārki (आर्कि) Saturn.
Āsā (आसा) (1) Direction. (2) Ten.
Āsanna (आसन्न) Approximate.
Āstamika (आस्तमिक) Pertaining to sunset.
Āspuṣjit (आस्पुष्टित) Venus.
Āhniya (आह्निय) (1) Pertaining to day. (2) A special astronomical term used by Bhāskara I. See MBh, i. 16-18.
Ina (इन) (1) Sun. (2) Twelve.
Indu (इन्दु) (1) Moon. (2) One,
Inducca (इनूक्का) Moon’s apogee, i.e., the remotest point of the Moon’s orbit.

Indriya (इन्द्रिय) Five.

Indavahah (इन्द्रह) Lunar day or tithi.

Isu (इसु) Five.

Iśta (इष्ट) Given, or desired, or chosen at pleasure.

Ucca (उच्च) The ucca is the apex of a planet’s orbit. It is of two kinds: (1) mandocca, i.e., the apex of slow motion, and (2) sīghrocca, i.e., the apex of fast motion. In Hindu astronomy, the mandocca is defined to be the remotest point of the planet’s orbit where the planet appears smallest\(^1\). It is therefore the same as the “apogee” of modern astronomy. The sīghrocca of the superior planets is an imaginary body which remains in the same direction as the mean Sun; that of an inferior planet lies approximately in the same direction from the Earth as the actual planet is from the Sun.

Uccabhukti (उच्चभूक्ति) (Daily) motion of the ucca; apsidal motion.

Utkrama (उत्क्रम) Reverse order.

Utkramaguna (उतक्रमगुण) Same as Utkramajāyā.

Utkramajīvā (उतक्रमजीवा) Same as Utkramajāyā.

Utkramajāyā (उतक्रमजया) Reversed-sine (= Radius × versed-sine).

Uttara (उत्तर) North.

Uttargola (उत्तरगोल) Northern hemisphere, i.e. the hemisphere lying to the north of the equator.

Udak (उदक) North.

Udayajyā (उदयज्या) The agrā of the rising point of a planet’s orbit.

Udayaprāna (उदयप्राण) Times of rising of the signs measured in asus.

Udayarāśipyaprānipinda (उद्यराशि-प्रानुपिन्द) The time in asus of rising of the rising sign.

Udayalagna (उदयलग्न) The rising point of the ecliptic, i.e., the horizon-ecliptic point in the east.

\(^1\) यत्र प्रहस्: सूक्तमा नक्षत्रभेदः कर्ष्यं महत्वात् स आकाशप्रदेश उच्चसंजितः। See Bhāskara I’s comm. on Ā, iii 4(i).
Udayāsu (उदयाः) Times of rising (of the signs) in asus.
Udyāstamaya (उदयास्तमय) Rising and setting.
Unnati (उननति) Elevation.
Uparāga (उपराग) Eclipse.
Uṣṇatejas (उष्णतेजस) Sun.
Uṣṇadidhiti (उष्णदिधिति) Sun.
Ṛṇi (ऋणी) Six.
Aindrāga (ऐंद्राग) The name of the sixteenth naksatra Viśākhā.
Aindri (ऐंद्री) East.
Oja (ओज) Odd.
Kakubh (ककुभ) Ten.
Kaksya (कक्ष्या) Orbit of a planet.
Kanyaka (कन्यका) The sign Virgo.
Kapāla (कपाल) Hemisphere.
Karana (करण) (1) Process; working. (2) The name of one of the principal elements of the Hindu Calendar.
Karkata (कर्कट) (1) A pair of compasses. (2) The sign Cancer.
Karna (कर्ण) (1) The hypotenuse of a right-angled triangle.
(2) The distance of a planet.
Karnasūtra (कर्णसूत्र) Hypotenuse-line.
Kalā (कला) Minute of arc.
Kalākarna (कलाकर्ण) The true distance of a planet in minutes of arc.
Kalanāṁ šeṣaḥ (कलानां शेषः) The residue of the minutes (kalāšeṣa).
Kaliyuga (कलीयुग) According to Bhāskara I, Kaliyuga is a period of 1080000 solar years. The current Kaliyuga began on Friday, February 18, B.C. 3102, at sunrise at Laṅka.
Kārmuka (कार्मुक) Arc.
Kalabhāga (कालभाग) Degrees of time. A degree of time is equivalent to 60 asus or 10 vinādis.
Kāṣṭha (काष्ठ) (1) Arc. (2) Direction.
Kāṣṭhā (काष्ठा) Direction.
Kīlaka (कीलक) Gnomon.
Kīlakagrāṇa (कीलकाग्राण) Same as Śaṅkagra.
Kuja (कुञ्ज) Mars.
Kujāsā (कुञ्जासा) South.
Kuṭila (कुटिल) Retrograde.
Kuṭṭa (कुट्ट) Pulveriser. See Kuṭṭākāra.
Kuṭṭana (कुट्टन) The Process of solving a pulveriser (Kuṭṭākāra).
Kuṭṭākāra (कुट्टकार) Pulveriser. Equations of the type
\[ N = ax + r = by + s \] (1)
or \[ ax - c = by \] (2)
are called in Hindu mathematics by the name \( \text{kut\text{\text{a}}-\text{k\text{\text{a}}}} \). A \( \text{kut\text{\text{a}}-\text{k\text{\text{a}}}} \) (pulveriser) is called \( \text{s\text{\text{a}}gra} \) (residual) or \( \text{niragra} \) (non-residual) according as it is of the type (1) or (2).

**Kumbha** (कुम्भ) The sign Aquarius.

**Kulira** (कुलीर) The sign Cancer.

**Kṛta** (कृत) Four.

**Kṛti** (कृति) Square.

**Kṛttikā** (कृत्तिका) The name of the third nakṣatra.

**Kendra** (केन्द्र) (1) Anomaly. The kendra is of two kinds: manda-kendra and ṣighra-kendra. The manda-kendra of a planet is equal to “the longitude of the planet minus the longitude of the planet’s mandoca (apogee),” and the ṣighra-kendra of a planet is equal to the “longitude of the planet’s ṣighroca minus the longitude of the planet.” (2) Centre.

**Kendrajyā** (केन्द्रज्या) The Rsine of kendra.

**Koṭi** (कोटि) See Bāhu.

**Koṭikā** (कोटिका) Same as Koṭi.

**Koṭiphala** (कोटिफल) The result obtained by multiplying the Rsine of koṭi due to a planet’s kendra by the epicycle and dividing the resulting product by 360.

**Koṭisādhana** (कोटिसाधन) Same as Koṭiphala.

**Krama** (क्रम) (1) Serial order.

(2) Odd quadrant.

**Kramaguṇa** (क्रमगुण) Same as Kramajyā.

**Kramajyā** (क्रमज्या) Rsine ( = Radius × sine).

**Krānti** (क्रांति) Declination.

**Kriya** (क्रिया) The sign Aries.

**Kṣamādina** (क्षमादिन) Civil day.

**Kṣitiguna** (क्षितिगुण) Same as Kṣitijyā.

**Kṣitijaguṇa** (क्षितिजगुण) Same as Kṣitiguna.

**Kṣitijā** (क्षितिजा) A corrupt form of Kṣitijyā.

**Kṣitijīvā** (क्षितिजीवा) Same as Kṣitijyā.

**Kṣitijyā** (क्षितिज्या) Earthsine. The distance between the rising-setting line and the line joining the points of intersection of the diurnal circle and the six o’clock circle.
GLOSSARY

Kṣitiḥdara (क्षितिघर) Seven.
Kṣitiputra (क्षितिपुत्र) Mars.
Kṣitimaurvī (क्षितिमृवी) Same as Kṣitiḥyā.
Kṣiptī (क्षिप्ति) Celestial latitude.
Kṣetranirmāṇa (क्षेत्रनिर्माण) Celestial longitude.
Kṣepa (क्षेप) Quantity to be added.
Kṣṇīdhara (क्षणीघर) Seven.
Kha (ख) Zero.
Khamadhyā (खमध्य) Meridian.
Khecara (बेनर) Planet.
Gagana (गणन) (1) Meridian. (2) Zero.
Gaganasya vṛttāṁ (गणनस्य वृत्त) The circumference of the sky. See Ambaroruparidhi.
Gaṇa (गण) Used in the sense of Bhagana.
Gata (गत) Traversed, elapsed.
Gati (गति) Motion. Generally used in the sense of “daily motion”.
Gantavya (गतत्वय) To be traversed.
Guna (गुण) (1) Multiple or multiplication. (2) Rsine. (3) Three.
Gūṇakāra (गुणकार) Multiplier, coefficient.
Gūṇapratāna (गुणप्रतान) Rsine.
Gūṇaphala (गुणफल) Bāhubhala and koṭiphala.
Guru (गुरु) Jupiter.
Gṛha (ग्रह) Sign.
Go (गो) The sign Taurus.
Gola (गोल) Hemisphere.
Golakhandā (गोलखण्ड) The semi-diameter of the (cestial) sphere. (गोल = sphere, खण्ड = half)
Golabheda (गोलभेद) Same as Golakhandā. (प्रेष = खण्ड = half)
Graha (ग्रह) (1) Planet. (2) Eclipse.
Grahāgaṇita (प्रहागणित) Astronomy.
Grahaçara (ग्रहचार) Motion of a planet.
Grahaṇa (ग्रहण) Eclipse.
Grahatanu (ग्रहतनु) A special term used by Bhāskara I. See MBh, i. 29.
Grahadeha (ग्रहदेह) Same as Grahatanu.
Grahayoga (ग्रहयोग) Conjunction of planets.
Grahaṇāṁ tanuḥ (ग्रहणां तनु) Grahatanu.
Grahoparaṅga (ग्रहोपरांग) Eclipse.
Grāsa (ग्रास) (1) Eclipse. (2) Measure of an eclipse. (2) Beginning of an eclipse.
Grāsamadhya (ग्रासमध्य) The middle of an eclipse.

Grāṣaṣṭalakā (ग्रास्तलका) A needle (or line) of length equal to the portion of the diameter eclipsed.

Grāśādi (ग्रासादि) The beginning of an eclipse.

Grāhaka (ग्राहक) The eclipsing body, the eclipser.

Grāhya (ग्राह्य) The eclipsed body.

Ghaṭīkā (घटिका) Same as Ghaṭī.

Ghaṭī (घटी) A unit of time equivalent to 24 minutes.

Ghana (घन) Cube.

Ghāta (घात) Product, multiplication.

Cakra (चक्र) Circle, twelve signs, or 360°.

Caturasra (चतुरस्र) Quadrilateral.

Candra (चन्द्र) (1) Moon. (2) One.

Candraka (चन्द्रक) Same as Candra.

Cara (चर) Ascensional difference. It is defined by the arc of the celestial equator lying between the six-o’clock circle and the hour circle of a heavenly body at rising.

Caradala (चरदल) Ascensional difference. See Cara.

Cala (चल) Śighrococa.

Calocca (चलोच्छ) Śighrococa.

Cāpa (चाप) (1) The sign Sagittarius. (2) Arc.

Cāra (चार) Motion or daily motion.

Citrā (चित्र) The name of the fourteenth nakṣatra.

Caitra (चैत्र) The name of the first month of the year.

Chāyā (चाया) (1) Shadow. (2) The position of the zenith distance.

Chāyādaighya (चायादेय्य) Same as Bhūcchāyādaighya.

Chāyābhramana (चायाभ्रमण) The path of the end of the shadow (of the gnomon).

Chidra (छिद्र) Nine.

Cheda (छेद) Divisor or denominator.

Chedāya (छेदया) Projection, or graphical representation.

Jaladhara (जलधर) Four.

Jaladhi (जलधि) Four.

Jalapadik (जलपदिक) West.

Jaleṣadik (जलेषदिक) West.

Jina (जिन) Twenty-four.

Jīva (जीव) Jupiter.

Jīvadina (जीवदिन) Thursday.
Jīvā (जीवा) (1) Rsine (= Radius x sine). (2) The Rsine-differences corresponding to the twenty-four divisions of the quadrant.

Jīvābhūkti (जीवाभूक्ति) True daily motion derived with the help of the table of Rsine-differences.

Jūka (जूक) The sign Libra.

Jnā (ज्ञ) The planet Mercury.

Jyā (ज्या) Same as Jīvā.

Jyāsaṅkalita (ज्यासंकलित) Used in the sense of "the given Jyā".

Jyau (ज्यो) Jupiter.

Tatparā (तत्परा) Third of arc, i.e., one-sixtieth of a second of arc.

Tattvā (तत्त्व) Twenty-five.

Tantra (तन्त्र) Principle, doctrine, theory, rule, method. Also, a class of astronomical works.

Tama (तम) (1) The shadow of the Earth, particularly, the section of the shadow cone where the Moon crosses it, by a plane perpendicular to the axis of the shadow cone. (2) The Moon’s ascending node.

Tamomaya (तमोमय) The Moon’s ascending node.

Tārakā (तारका) Star.

Tārā (तारा) Star.

Tārāgraha (ताराग्रह) The star-planets. The planets Mars, Mercury, Jupiter, Venus, and Saturn are called star-planets (tārāgraha) in Hindu astronomy.

Tīgmaṃśu (तिगमांश) (1) The Sun. (2) Twelve.

Tithi (तिथि) (1) Lunar day (called tithi). (2) Time of conjunction or opposition of the Sun and Moon. (3) Time of beginning, middle, or end of eclipse. (4) Fifteen. (5) Thirty.

Tīthi-prāṇāsa (तिथिप्राणास) Omitted tithis.

Tīthyaṇa (तिथ्यण) Time of conjunction or opposition of the Sun and Moon.

Tīryak (तिर्यक) (1) Oblique. (2) Transverse.

Twāga (तुग) Same as Ucca.

Turśya (तुर्श्य) One-fourth.

Tuṇa (तुणा) The sign Libra.

Tuṇādharā (तुणाधर) The sign Libra.

Trīṃghaṇu (त्रिमघुण) The Rsine of three signs, i.e.,
the radius or 3438'.
Triṣṭīya (त्रिस्त्रीय) Radius or 3438'.
Tribhavana (त्रिभवन) Three signs.
Trimaurva (त्रिमौर्व) Radius.
Trairāṣṭika (तौरास्तिक) Rule of Three.
Dala (दल) Half.
Daśaguna (दशगुण) The ten Rsines, viz. Sun's udayajyā, Sun's madhyajyā, Sun's ṅṛkṣeṣapajyā, Sun's ṅṛgijyā, Sun's ṅṛgatijyā, Moon's udayajyā, Moon's madhyajyā, Moon's ṅṛkṣeṣapajyā, Moon's ṅṛgijyā, and Moon's ṅṛgatijyā.
Daśajīvā (दशजीवा) Same as Daśaguna.
Dasra (दस्र) Two.
Dahana (दहन) Three.
Dik (दिक) (1) Direction. (2) Ten.
Dikka (दिक्क) Direction.
Ditisūnupūjita (दितिसूनुपूजित) Venus.
Dīna (दीन) (1) Day. (2) Fifteen.
Dinagana (दिनागन) Same as Ahargaṇa.
Dinamāna (दिनमान) Measure (or length) of the day.
Dinaraṭi (दिनराठि) Ahargaṇa.

Dīnaṁ ganaḥ (दिनान्म गणः) Same as Ahargaṇa.

Divasa (दिवस) (1) Day. (2) Ahargaṇa.
Divasagunaṛdha (दिवसगुणर्द्ध) The day radius.
Divasajīvā (दिवसजीवा) The day radius.
Divasayojana (दिवसयोजन) The number of yojanas that a planet traverses in a day.
Divasavistarabheda (दिवसविस्तारभेद) The day radius.
Divāguṇa (दिवागुण) The day radius.
Divicara (दिविचर) (1) Seven. (2) Planet.

Dis. (दिश) (1) Direction. (2) Ten.
Dṛkkṣeṇa (दृक्षेप) The dṛkkṣeṇa is the shortest arcual distance of the planet's orbit from the zenith. It is also used for the Rsine of that distance.

Dṛggaṭi (दृग्गाठी) Arc corresponding to the Dṛggaṭiṭyā.

Dṛggaṭiṭyā (दृग्गाठी) The dṛggaṭiṭyā is the distance from the zenith of the plane of a planet's circle of celestial longitude, or the Rsine of the shortest distance from
the zenith of a planet's circle of celestial longitude.

Drγguna (द्रणुगण) The sine of zenith distance.

Drγjivā (द्रणीवा) The sine of zenith distance.

Drγjyā (द्रण्या) The sine of zenith distance.

Dr̥ha (द्रह) Prime.

Dr̥ṣya-candra (द्रष्यचन्द्र) The longitude of the Moon corrected for the visibility corrections.

Devaṃya (देवमुय्या) Jupiter.

Devaṃantari (देवंमन्त्रि) Jupiter.

Desakāla (देसकाल) Used in the sense of desāntara-kāla, i.e., the longitude-correction in terms of time.

Desajāta-kāla (देशजातकाल) See Desakāla.

Desāntara (देसान्तर) The longitude of the place. That is, either the distance of the local place from the prime meridian, or the difference between the local and standard times.

Desāntara-karma (देसान्तर-कर्म) Correction for the longitude of the place, the longitude-correction.

Desāntara-ghaṭī (देसान्तर-घटी) Desāntara in ghaṭīs.

Deha (देह) Used in the sense of grahadeha. See Grahadeha.

Dyugana (दुग्नाण) Ahargana.

Dyujīyā (दुज्या) The day radius.

Dyuti (दुर्ति) Shadow (meaning "the shadow of the gnomon").

Dyuti-karna (दुरतिकर्ण) The hypothenuse of the shadow (of the gnomon).

Dyudala (दुदल) The day radius.

Dyurāsi (दुरासि) Ahargana.

Dyuvyāsa (द्रुव्यास) The day radius.

Dyuvyāsakhaṇḍa (द्रुव्यासकंड) The day radius.

Dyuvyāsābheda (द्रुव्यासाभेद) The day radius.

Dyuvāyāsārdha (द्रुव्यासार्ध) The day radius.

Dvyagra (द्याग्र) A sāgra kūṭā-kāra (residual pulveriser) with two residues.

Dhāna (धन) Addition.

Dhanisthā (धनिष्ठ) The name of the twenty-third nakṣatra.

Dhanuḥ (धनु) (1) Arc. (2) The sign Sagittarius.

Dhanuḥ-khaṇḍa (धनु-कण्ठ) In Hindu astronomy, the qua-
drant of a circle is divided into twenty-four equal parts and these parts are known as kāśīha, dhanu, dhanukkhāṇḍa, dhanurbhāga, etc.

**Dhanurbhāga** (धनुरभाग) 225°.

**Dhanus** (धनु) (1) Arc. (2) 225°.

**Dhanvin** (धनविन) The sign Sagittarius.

**Dharaṇīdina** (धरणीदिन) Civil day.

**Dharādivasa** (धरादिवस) Civil day.

**Dharāsuta** (धरासुत) Mars.

**Dhātridhara** (धात्रीधर) Seven.

**Dhti** (धृति) Eighteen.

**Dhruvaka** (ध्रुवक) A technical term. See MBh, i:29.

**Naksattra** (नक्षत्र) (1) Star. (2) Asterism. (3) Twenty-seven.

**Naksatragana** (नक्षत्रगण) Same as Bhagana.

**Naksatra-bheda** (नक्षत्रभेद) Occultation of stars.

**Nakha** (नख) Twenty.

**Naga** (नग) Seven.

**Natabhāga** (नतभाग) The degrees (bhāga) of zenith distance (nata).

**Nataṁśa** (नतांश) Zenith distance.

**Nati** (नति) (1) The meridian zenith distance. (2) Celestial latitude as corrected for parallax in latitude. (3) Parallax in latitude.

**Natiyā** (नतिया) The Rsine of the meridian zenith distance.

**Nanda** (नन्द) Nine.

**Nabha** (नभ) Zero.

**Nara** (नर) (1) The sign Gemini. (2) Gnomon. (3) The Rsine of altitude.

**Nā** (न) The Rsine of altitude.

**Nādīka** (नादिक) A unit of time equivalent to 24 minutes.

**Nādi** (नादी) See Nādīka.

**Nirakṣa** (निरक्ष) Equator.

**Nirakṣāsu** (निरक्षासु) Asus of the right ascension, i.e., the time in asus of rising at the equator.

**Nirapavartita** (निरपवर्तित) Unabraded, unabridged.

**Niśakara** (निशाकर) (1) Moon. (2) One.

**Niścalakriyā** (निश्चलक्रिया) Method of successive approximations.

**Niśvāsalava** (निश्वासलव) Asus.

**Nṛ** (न) Gnomon.
Netra (नेत्र) Two.
Nemi (नेमि) Circumference, periphery.
Paśa (पश्चा) (1) Lunar fortnight, period from new moon to full moon, or from full moon to new moon. (2) Two
Pada (पद) (1) Quadrant. (2) Square root.
Parakrānti (परक्कांति) (Sun's) greatest declination, or obliquity of the ecliptic.
Paramāpama (परमापम) Same as Parakrānti.
Paridhi (परिधि) (1) Circumference, periphery. (2) Epicycle.
Parilekha (परिलेख) Projection, graphical representation.
Parvata (परवत) Seven.
Parvamadhya (परवमध्य) The middle of the eclipse.
Pala (पल) Latitude.
Palajīvā (पलजीवा) The Rsine of the latitude.
Palajyā (पलज्या) The Rsine of the latitude.
Palabhāga (पलभाग) The degrees of the latitude.
Palāṅgula (पलाङ्गुल) Used in the sense of 'palabhāṅgula', i.e., the aṅgulas of the equinoctial midday shadow.
Palāṁśa (पलांशा) The degrees of the latitude.
Paścārdha (पश्चार्ध) The western half.
Pāta (पात) The ascending node of a planet's orbit (on the ecliptic).
Pātabhāga (पातभाग) The degrees of the longitude of the ascending node.
Puśkara (पुष्कर) Three.
Puṣvalagna (पुष्वलक्ष) The horizon-ecliptic point in the east.
Paṇkti (पांक्ति) Ten.
Pratimaṇḍala (प्रतिमण्डल) Eccentric.
Pratimaṇḍala-karma (प्रतिमण्डल-कर्म) Processes under the eccentric theory.
Prabhā (प्रभा) (1) The shadow of the gnomon. (2) The Rsine of the zenith distance.
Pralayāstithānām (प्रलयास्तिथानाम) Omitted lunar days.
Prāśāra (प्रासार) The statement of possible combinations in a serial order.
Prāgrāsa (प्राग्रास) The first contact in an eclipse.
Prāṇa (प्राण) Same as Asu.
Prāḷeyaraśmi (प्रालेयरश्मि) One.
Pronnati (प्रोणति) Altitude...

Phala (फल) (1) Result. (2) Correction.

Bava (वव) The first of the seven movable karaṇas. The karaṇa is one of the five important elements of the Hindu Calendar.

Bāhula (बहुल) The nakṣatra Kṛttikā.

Bāhu (बाहु) (1) The base (of a right-angled triangle). The upright of a right-angled triangle is called kōṭi. (2) The bāhu corresponding to a planet’s anomaly. This is the arcual distance of the planet from its apogee or perigee whichever is nearer. Suppose that \( \theta \) is the anomaly of a planet (or any arc, whatever). If \( \theta \) is less than \( \pi/2 \), \( \theta \) itself is the bāhu; if \( \theta \) is greater than \( \pi/2 \) but less than \( \pi \), \((\pi-\theta)\) is the bāhu; if \( \theta \) is greater then \( \pi \) but less than \( 3\pi/2 \), \((\theta-\pi)\) is the bāhu; and if \( \theta \) is greater than \( 3\pi/2 \), \((2\pi-\theta)\) is the bāhu. The complement of the bāhu is called kōṭi.

Bāhuka (बाहुक) Same as Bāhu.

Bāhujyā (बाहुज्या) The Rsine of the bāhu (of a planet’s anomaly).

Bāhuphala (बाहुफल) See notes on MBh, iv. 6.

Bāhoḥ phalam (बाहोः फल) Same as Bāhuphala.

Bimba (विंभ) The disc of a planet.

Bimbārdha (विंभर्ध) The semi-diameter of the disc.

Budhasā (बुधशा) North.

Bhām (भा) Twenty-seven.

Bhaga (भग) The nakṣatra Purvā-phālgunī, the regent of which is Bhaga.

Bhagaṇa (भगण) (1) The revolution-number of a planet, i.e., the number of revolutions that a planet performs in a certain period. The revolutions given by Bhāskara I correspond to a yuga, i.e., to a period of 43,20,000 years. (2) The nakṣatras. (3) Twelve signs (or 360°).

Bhava (भव) Eleven.

Bhavana (भवन) Sign.

Bhāga (भाग) (1) Part, fraction. (2) Division. (3) Degree.

Bhāgalabdha (भागलब्ध) Quotient.
Bhāgaseśa (भागसेश) The residue of the degrees.

Bhāgahāra (भागहार) Divisor.

Bhāgahāraka (भागहारक) Same as Bhāgahāra.

Bhājya (भाज्य) Dividend

Bhārgava (भार्गव) Venus.

Bhidah (भिद) Half.

Bhukti (भुक्ति) Motion, or daily motion.

Bhūjā (भुज) Same as Bāhu.

Bhūjā (भूजा) Same as Bhūja.

Bhūjāntara (भूजान्तर) Correction for the equation of time due to the eccentricity of the ecliptic.

Bhūjāphala (भूजाफल) The equation of the centre.

Bhūchchhayā (भूच्छहाय) The Earth’s shadow.

Bhūchchhayādairghya (भूच्छहायादिर्घ्य) The length of the Earth’s shadow, i.e., the distance of the vertex of the shadow cone from the Earth’s centre.

Bhūjyā (भूज्या) See Kṣitijyā.

Bhūta (भूत) Five.

Bhūdina (भूदिन) Civil day.

Bhūdivasa (भूदिवस) Civil day.

Bhūdhara (भूधर) Seven.

Bhūbhṛt (भूभृत) Seven.

Bhūmidina (भूमिदिन) Civil day.

Bhrigu (भृगु) Venus.

Bhrigu (भृगु) Venus.

Bhedā (भेद) (1) Half. (2) Occultation of a heavenly body.

Bhogā (भोग) Motion.

Bhauṣa (भूष) Mars.

Maghavadguru (मघवद्गुरु) Jupiter.

Maghā (मघा) Name of the tenth nakṣatras.

Mandala (मण्डल) Circle; a collection of 12 signs.

Mandalamadhyā (मण्डलमध्य) The centre of a circle.

Matī (मति) An optional number.

Matsya (मत्स्य) Fish-figure.

Madhu (मधु) Caitra, the first month of the year.

Madhyakramī (मध्यक्रान्ति) The declination of the meridian-ecliptic point.

Madhyacchhayā (मध्यच्छहाय) The midday shadow (of the gnomon).

Madhyajātaḥ lambakah (मध्यजातः लम्बकः) The upright due to the meridian-ecliptic point,
Glossary

i.e., the Rsine of the altitude of the meridian-ecliptic point.

Madhyajjā (मध्यज्ञा) The Rsine of the zenith-distance of the meridian-ecliptic point; the meridian-sine.

Madhyaparīśhitaṁlabāka (मध्यपरिशिष्ठतलम्बक) Same as Madhyajjatāḥ labākāḥ.

Madhyalagna (मध्यलग्न) Meridian-ecliptic point.

Madhyasūryāvanāma (मध्यसूर्यावानाम) The zenith distance of the midday Sun, or the meridian zenith distance of the Sun.

Madhyāvanati (मध्यावानति) The zenith distance of the midday Sun.

Mandakendra (मन्दकेन्द्र) Manda anomaly (=longitude of the planet minus longitude of the planet’s apogee).

Mandāpata (मन्दापत) See MBh, vii. 30.

Mandaphala (मन्दफल) Correction due to the planet’s mandocca. In the case of the Sun and Moon, the equation of the centre.

Mandamaurtaphalacāpa (मन्द-मूर्तिपालचा) Same as Mandaphala.

Mandavrīta (मन्दव्रीत) Manda epicycle.

Mandasiddha (मन्दसिद्ध) Corrected for the mandaphala.

Mandasiddhi (मन्दसिद्धि) Correction (of a planet) for the mandaphala.

Mandaṁtyājiiva (मन्दांत्याजिव) The present Rsine-difference corresponding to the mandakendra i.e., the Rsine-difference of the elementary arc in which the planet lies.

Mandocca (मन्दोच्च) The apogee of a planet. See Ucca.

Mandocacakarna (मन्दोच्चकर्ण) See Mandakarna.

Mandoccekendra (मन्दोच्चकेन्द्र) See Mandakendra.

Mandoccavṛttā (मन्दोच्चवृत्त) Manda epicycle.

Mithuna (मिथुन) The sign Gemini.

Mīna (मीन) (1) Fish-figure, (2) the sign Pisces.

Muni (मुनि) Seven.

Mūla (मूल) Square root.

Mrīga (मृग) The sign Capricorn.

Mēsa (मेष) The sign Aries.
Maitra (मैत्र) The *nakṣatra* Anurādhā, the regent of which is Mitra.

Mokṣa (मोक्ष) The separation of the eclipsed body after an eclipse.

Maurika (मौरिक) Minute of arc.

Maurvi (मौर्वी) Rsine.

Yantra Instrument.

Yama (यम) (1) Saturn. (2) Name of the second *nakṣatra* Bharani, whose divinity is Yama. (3) Two.

Yamala (यमल) Two.

Yāmya (याम्य) South.

Yāmyagola. (याम्यगोल) The southern hemisphere, i.e., the hemisphere lying to the south of the equator.

Yāmyottara (याम्योत्तर) South-north.

Yāmyottarāyata (याम्योत्तरायत) Directed south-to-north.

Yugala (युगल) Two.

Yugma (युगम) Even.

Yoga (योग) (1) Addition. (2) Conjunction of two heavenly bodies.

Yogatārā (योगतारा) Junction-stars. These are those prominent stars of the twenty-seven *nakṣatras* which were used by the Hindu astronomers for the study of the conjunction of the planets, especially the Moon, with them.

Yogabhāga (योगभाग) The degrees of the longitudes of the junction-stars.

Yojana (योजन) The *yojana* is a measure of distance. The length of a *yojana* has differed at different places and at different times. The *yojana* of Āryabhaṭa I and Bhāskara I is roughly equivalent to 7½ miles.

Randhra (रन्ध्र) Nine.

Ravi (रवि) (1) Sun. (2) Twelve.

Ravija (रविज) (1) Saturn. (2) A special term used by Bhāskara I. See MBh, i. 27.

Ravijādivasa A special term used by Bhāskara I. See MBh, i. 28.

Rasa (रस) Six.

Rāma (राम) Three.

Rāvi (रावि) (1) Quantity. (2) Sign.

Rāṣṭiṣṭvā (राष्टिष्ठ्वा) The Rsine of one sign, i.e., Rsin (30°).

Rāhu (राहु) The Moon’s ascending node.
Lambana (सम्बन) Parallax in longitude; or, in particular, the difference between the parallaxes in longitude of the Sun and Moon.

\[ \text{Lambanaliptā (लम्बनलिप्ता)} \]
\[ \text{Lambana in longitude in terms of minutes of arc.} \]

\[ \text{Lambanāntara (लम्बनान्तर)} \]
\[ \text{The lambana-difference.} \]

\[ \text{Lambanāntaranādikā (लम्बनान्तर-नादिका)} \]
\[ \text{The nādīs of the lambana-difference, or the lambana-difference in terms of nādīs.} \]

\[ \text{Lava (लव)} \]
\[ (1) \text{Part, portion, fraction.} \]
\[ (2) \text{Degree.} \]

\[ \text{Liptā (लिप्ता)} \]
\[ \text{Minute of arc.} \]

\[ \text{Liptikā (लिप्तिका)} \]
\[ \text{Same as Liptā.} \]

\[ \text{Liptikā vipūrvā (लिप्तिका विपूर्वा)} \]
\[ \text{Viliptikā; second of arc.} \]

\[ \text{Vakra (वक्र)} \]
\[ \text{Retrograde.} \]

\[ \text{Vakragati (वक्रगति)} \]
\[ \text{Retrograde motion.} \]

\[ \text{Vakragamana (वक्रगमन)} \]
\[ \text{Retrograde motion.} \]

\[ \text{Vakrigraha (वक्रग्रह)} \]
\[ \text{A planet in retrograde motion.} \]

\[ \text{Vacasāṁ patik (वचसां पतिक)} \]
\[ \text{Jupiter.} \]

\[ \text{Vatsara (वत्सर)} \]
\[ \text{Year.} \]

\[ \text{Vapu (वपु)} \]
\[ \text{The body (globe or disc) of a planet.} \]

\[ \text{Varga (वर्ग)} \]
\[ \text{Square.} \]

\[ \text{Vartamāna (वर्तमान)} \]
\[ \text{Present, current.} \]

\[ \text{Labdha (लब्ध)} \]
\[ \text{Quotient.} \]

\[ \text{Lamba (लब्ध)} \]
\[ \text{The Rsine of the colatitude (of the place).} \]

\[ \text{Lambaka (लम्बक)} \]
\[ \text{The Rsine of the colatitude.} \]

\[ \text{Lambakaguna (लम्बकगुण)} \]
\[ \text{Same as Lambaka.} \]

\[ \text{Laṅkā (लंका)} \]
\[ \text{A place in 0 latitude and 0 longitude.} \]
\[ \text{Also see supra, p. 47.} \]

\[ \text{Laṅkarāśyaudyā (लंकराश्यूद्य)} \]
\[ \text{Times of rising of the signs at Laṅkā, or right ascensions of the signs.} \]

\[ \text{Laṅkodaya (लंकोदय)} \]
\[ \text{Times of rising (of the signs) at Laṅkā, or right ascensions (of the signs).} \]

\[ \text{Rudra (रूद्र)} \]
\[ \text{Eleven.} \]

\[ \text{Rudhira (रूढ़िर)} \]
\[ \text{Mars.} \]

\[ \text{Rūpa (रूप)} \]
\[ \text{One.} \]
Vartamānaguna (वर्तमानगुण) The present (or current) Rsine-difference, i.e., the Rsine-difference of the elementary arc occupied by a planet.

Vṛṣapa (वृषप) The lord of the year, i.e., the planet after whose name the first day of the year bears its name.

Valana (वलन) Deflection. Valana relates to an eclipsed body. It is the angle subtended at the body by the arc joining the north point of the celestial horizon and the north pole of the ecliptic. Valana is generally divided into two components, (i) Aksavalana and (ii) Ayanavalana. The Aksavalana is the angle subtended at the body by the arc joining the north point of the celestial horizon and the north pole of the equator. The Ayanavalana is the angle subtended at the body by the arc joining the north poles of the equator and the ecliptic. The Valana is also defined as follows: The great circle of which the eclipsed body is the pole is called the horizon of the eclipsed body. Suppose that the prime vertical, equator, and the ecliptic intersect the horizon of the eclipsed body at the points A, B and C towards the east of the eclipsed body. Then arc AB is called the Aksavalana, arc BC is called the Ayanavalana and arc AC is called Valana.

Valana is also called sapaṭavālana.

Vasu (वसु) Eight.

Vahni (वह्नि) Three.

Vāruṇī (वारुणी) West.

Vi (वि) Celestial latitude. Evidently, Vi is an abbreviated form of vikṣepa.

Vikalā (विकला) Second of arc.

Vikāṣṭha (विकास्थ) The arc of celestial latitude.

Vikṣipti (विक्षिप्ति) Celestial latitude.

Vikṣepa (विक्षेप) Celestial latitude.

Vikṣepajjā (विक्षेपज्जा) The Rsine of celestial latitude.

Vikṣepāṃśa (विक्षेपांश) The degrees of celestial latitude.
Vighaṭikā (विघटिका) A unit of time, equivalent to 24 seconds.

Vidiś (विदिः) Contrary direction.

Vināḍikā (विनाडिका) Same as Vighaṭikā.

Vināḍi (विनाडी) Same as Vināḍikā.

Viparītaguna (विपरीतगुण) Reversed-sine.

Vipulacchāyā (विपुलचाया) Great shadow, meaning “the Rsine of the zenith distance”.

Vipulanara (विपुलनर) Great gnomon, meaning “the Rsine of altitude.”

Vimandala (विमण्डल) The orbit of a planet.

Vimardārdha (विमर्दार्ध) Half the duration of totality of an eclipse.

Vimaṇurika (विमोरिक) Second of arc.

Viyat (वियत्) Zero.

Vilagna (विलग्न) The horizon-ecliptic point in the east.

Viliptā (विलिप्ता) Second of arc.

Viliptikā (विलिप्तिका) Same as Viliptā.

Vivara (विवर) Difference, intervening space.

Vīśākhā (विशाखा) Name of the sixteenth naksattra.

Vīḍesa (विशेष) Difference.

Vīḍleṣa (विश्लेष) Difference.

Vīṣva (विष्व) Thirteen.

Vīṣama (विषम) Odd.

Vīṣaya (विषय) Five.

Vīṣuvajyā (विषुवज्या) The Rsine of the latitude (of a place).

Vīṣuvat (विषुवत्) The equator.

Vīṣuvatkarṇa (विषुवतकर्ण) The hypotenuse of the equinoctial midday shadow.

Vīṣuvatprabhā (विषुवतप्रभा) The equinoctial midday shadow.

Vīṣuvadudayāraśippānapind (विषुवद्धदयारशिप्पानपिंद) Time in asus of rising of the signs at the equator, i.e., right ascension of the signs in terms of asus.

Vīṣkambha (विषकम्भ) Diameter.

Vīṣṇukrama (विष्णुक्रम) Three.

Vistara (विस्तर) Same as Vistāra.

Vistāra (विस्तर) (1) Diameter. "Vyāsa, viṣkambha, and vistāra are synonyms", says Bhāskara I. (2) Length,
breadth, etc. “Āyama, vistāra, and dairghya are synonyms,” says Bhāskara I.

Vihaṅgama (विहंगम) Planet.
Vihaṇa (विहण) Planet.
Viḥāyas (विहायस्) Zero.
Viṣṭa (वृष्ट) (1) Circle. (2) Epicycle.
Viṣṭasāṅkhyā (वृष्टसंख्या) The length of the circumference of a circle.
Viṇḍa (वृण्ड) Cube.
Viṛṣa (वृष) The sign Taurus.
Veda (वेद) Four.
Veśakuti (वेशकुटि) Time-pulveriser. See notes on MBh, i. 49.

Vaiḍhṛta (वैधृत) An astronomical phenomenon. See MBh, iv. 35.

Vaiśuwasī chāyā (वैषुवसी छाया). The equinoctial midday shadow.

Vyaṭipāta (व्यटिपाट) An astronomical phenomenon. See MBh, iv. 35.

Vyāsa (व्यास) Diameter.
Vyāsakhaṇḍa (व्यासकण्ठ) Radius.
Vyāsakhaṇḍanicaya (व्यासकण्ठ-निचय) same as Vyāsakhaṇḍa.

Vyāsārdha (व्यासार्ध) Radius or 3438°.

Vyoma (व्योम) Zero.
Śakratāraka (शक्रतारक) The nakṣatra Jyeṣṭhā, whose regent is Indra.
Śakraguru (शक्रगुरु) Jupiter.
Śaṅku (शंकु) (1) Gnomon. (2) The Rsine of altitude (of a heavenly body).

Śaṅkvagra (शंक्वग्र) The distance of the projection of a heavenly body on the plane of the celestial hori- zon from the planet’s rising-setting line.

Śaṅkvagrajīva (शंक्वग्रजीवा) Same as Śaṅkvagra.

Śatabhīṣak (शतभिषक) The nakṣatra Śatabhikā.
Śapharikā (शफरिका) A fish-figure.
Śara (शर) (1) Rversed-sine. (2) Five.
Śaśi (शश) (1) The Moon. (2) One.
Śaśija (शशिज) Lunar.
Śālin (शालिन) One.
Śikhi (शिखि) Three.
Śilimukha (शिलीमुख) Five.
Śiva (शिव) Eleven.
Śīghra (शीघ्र) Same as Śīghrocca.
Śīghrakarna (शीघ्रकर्ण) The distance of a planet obtained by the Śīghrocca process.
Śīghrakendra (शीघ्रकेन्द्र) The Śīghra anomaly. See Kendra.
Śīghrakendrapāla (शीघ्रकेन्द्रपाल) Śīghraphala, i.e., correction due to the Śīghrocca.
Śīghrajaḥ karnāḥ (शीघ्रज कर्ण) = Śīghrakarna.
Śīghranyācāpāca (शीघ्रनञ्चापाचा) = Śīghraphala.
Śīghraparidhī (शीघ्रपरिधि) Śīghra epicycle.
Śīghrapāta (शीघ्रपात) See MBh, vii. 31.
Śīghravṛtti (शीघ्रवृत्ति) Śīghra epicycle.
Śīghraśiddha (शीघ्रसिद्ध) Corrected for the Śīghraphala.
Śīghrāntyajīvā (शीघ्रान्त्यजीवा) The present Rṣine-difference relating to the Śīghra (kendra).
Śīghrocca (शीघ्रोच्च) See Ucca.
Śīghroccavṛti (शीघ्रोच्चवृत्ि) Śīghra epicycle.
Śītakīrana (शीतकीरण) (1) Moon. (2) One.
Śītarāsmi (शीतरास्मि) (1) Moon. (2) One.
Śītāṃśu (शीतांशु) (1) Moon. (2) One.
Śukla (सुक्ल) The illuminated part of the Moon’s disc; the phase of the Moon.
Śrigonnati (श्रिगोन्नति) The elevation of the Moon’s horns.
Śaila (शैल) Seven.
Śodhana (शोधन) Subtraction.
Śodhānīya (शोधनीय) A subtractive quantity technically called śodhānīya or śodhya. See MBh, i. 28.
Śodhya (शोध्य) See Śodhanīya.
Śaukīlya (शौकील्य) The illuminated part of the Moon’s disc.
Śravana (श्रवण) (1) Name of the 22nd naksatra. (2) The Hypotenuse (of a right-angled triangle).
Śamskṛta (संस्कृत) Corrected.
Śakalaguna (सकलगुण) Radius or 3438’.
Śāṅkālita (संकलित) Sum, total.
Śannati (सानति) Meridian zenith distance.
Śama (सम) Even.
Śamamāṇḍala (सममाण्डल) The prime vertical.
Samamandala[sanku (सममण्डलसंकु) The Rsin of the prime vertical altitude.
Samarekha (समरेखा) The prime meridian.
Samalipta (समलिप्त) Two planets are said to be samalipta (समलिप्त) when their longitudes are equal up to minutes.
Samavalambarjay[a (समवलम्बरजया) The Rsin of the colatitude.
Saravapama (सरवपम) The greatest declination (of the Sun), i.e., the obliquity of the ecliptic.
Sagara (सागर) Four.
Sarpamastaka (सारपमस्तक) An astronomical phenomenon.
See MBh, iv. 35.
Simha (सिंह) The sign Leo.
Sita (सित) (1) The illuminated part of the Moons disc; the phase of the Moon. (2) The light half of the month. (3) Venus.
Sitakhaga (सितखाग) Venus.
Sitapaksa (सितपक्ष) The light half of a lunar month, light fortnight.
Sitabindu (सितबिंदु) That point of the Moon’s diameter which lies at the end of the illuminated part of the Moon.
Sitamana (सितमान) The measure of the illuminated part of the Moon’s disc.
Suranathaguru (सुरनाथगुरु) Jupiter.
Surapadik (सुरपदिक) East.
Surejya (सुरेज्य) Jupiter.
Suri (सूरि) Jupiter.
Surya (सूर्य) (1) Sun. (2) Twelve.
Suryakas[y][a (सूर्यकाश्या) The orbit of the Sun, the ecliptic.
Suryaja (सूर्यज) Saturn.
Saimhikeya (सैम्हीक्य) The ascending node of the Moon’s orbit. (Saimhikeya literally means Rahu, son of Simhikā).
Somaja (सोमज) Mercury.
Somasunu (सोमसुनु) Mercury.
Saumya (सौम्य) (1) North. (2) The naksatra Mrgaśirā. (3) Mercury.
Sauri (सौरि) Saturn.
Sthiti (स्थिति) Duration (of an eclipse).
Sthitidala (स्थितिदल) Half the duration (of an eclipse).
Sthityardha (स्थित्यार्द्ध) Half the duration (of an eclipse).

Sthula (स्थूल) Gross, approximate.

Sparśa (स्पर्श) Contact.

Sparśakāla (स्पर्शकाल) Time of the first contact (in an eclipse).

Spasṭa (स्पष्ट) True, corrected.

Sphuta (स्फुट) True.

Sphuṭamadhyya (स्फुटमध्य) True-mean; the true-mean planet.

Sphuṭamadhyama (स्फुटमध्यम) Same as sphuṭamadhyya.

Sphuṭayojana (स्फुटयोजन) Used in the sense of sphuṭayojanakarṇa.

Sphuṭayojanakarṇa (स्फुटयोजनकर्ण) The true distance (of a planet) in terms of yojanas.

Sphuṭavṛtta (स्फुटवृत्त) True or corrected epicycle.

Svara (स्वर) Seven.

Harīja (हरिजा) Horizon.

Hāra (हार) Divisor.

Hārarāsi (हारराषि) Divisor.

Himāṃstu (हिमांशु) (1) Moon. (2) One.

Hīna (हीन) (1) Less. (2) Omitted lunar day (hīnadīvasa).

Hīnadīvasa (हीनदिवस) Omitted lunar day.

Hīnarātra (हीनरात्र) Same as Hīnadīvasa.

Hutākṣa (हुताक्ष) Three.