History of Science in South Asia

The Table Text Jagadbhūṣaṇa of Haridatta
The First Chapter on the Sun and the Moon

Keshav Melnad, Clemency Montelle et Ramasubramanian K.

Volume 12, 2024

URI : https://id.erudit.org/iderudit/1113587ar
DOI : https://doi.org/10.18732/hssa102

Aller au sommaire du numéro

Éditeur(s)

University of Alberta Library

ISSN

2369-775X (numérique)

Découvrir la revue

Citer cet article

Melnad, K., Montelle, C. & K., R. (2024). The Table Text Jagadbhūṣaṇa of Haridatta: The First Chapter on the Sun and the Moon. *History of Science in South Asia*, *12*, 32–94. https://doi.org/10.18732/hssa102

Résumé de l'article

In the seventeenth century, the astronomer Haridatta of Mewar, Rājasthān, produced a table text named the Jagadbhūṣaṇa (epoch Śaka 1560, or 1638 CE). This table text provided calendar makers with a complete set of data and associated procedures for the computation of the annual calendar known in Sanskrit as a pañcāṅga. The tables are huge and represent an enormous computational effort, and the astronomical structure that underlies them is somewhat akin to the Babylonian Goal Year texts and similar cyclic schemes set out by Ptolemy and al-Zarqālī. The accompanying text consists of around one hundred and thirty verses organised into five chapters. This article is the first in a series that presents the Sanskrit text of the Jagadbhūṣaṇa along with a translation and a detailed technical commentary of the text and analysis of the associated tabular material, chapter by chapter. In the opening chapter, Haridatta begins the work with a lengthy encomium to his patron, Mewar Rajput Jagatsiṃha, before describing the procedures by which the true longitudes and motions of the sun and the moon can be determined using the accompanying tabulated data.

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MLA style citation form: Keshav Melnad, Clemency Montelle, Ramasubramanian K.. "The Table Text *Jagadbhūṣaṇa* of Haridatta: The First Chapter on the Sun and the Moon." *History of Science in South Asia*, 12 (2024): 32–94. DOI: 10.18732/hssa102.

Online version available at: http://hssa-journal.org

HISTORY OF SCIENCE IN SOUTH ASIA
A journal for the history of all forms of scientific thought and action, ancient and modern, in all regions of South Asia, published online at http://hssa-journal.org

ISSN 2369-775X

Publisher:

History of Science in South Asia

Principal Contact:

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The electronic versions were generated from sources marked up in LaTeX on a computer running GNU/LINUX operating system. PDF was typeset using XeTeX from the most recent TeXLive. The base font used for Latin script and oldstyle numerals was TeX Gyre Pagella developed by GUST, the Polish TeX Users Group. Devanāgarī and other Indic fonts are by Tiro Typeworks or Sanskrit 2003 from Omkarananda Ashram.

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HISTORY OF SCIENCE IN SOUTH ASIA 12 (2024) 32–94
DOI: 10.18732/HSSA102

1 INTRODUCTION

THE JAGADBHŪṢAṆA IS A TABLE TEXT composed in the seventeenth century by the astronomer Haridatta, the son of Harijī, who worked at the court of Jagatsiṃha (r. 1628–1652) in Mewar, south-central Rājasthān.[1] The work is comprised of five chapters accompanied by a large set of numerical tables. The primary purpose of this table text was to provide astronomers with data to construct the annual calendar (*pañcāṅga*). The tables themselves are enormous—comprised of many thousands of rows of numerical data. Venus alone has over 6000 rows of entries. Despite its size, this table text appears to have been popular, as there exist at least 26 manuscript copies (Pingree 1968: 55) in various libraries and repositories across the world.

The title of this work "*Jagadbhūṣaṇa*" can be construed as a clever equivoque to felicitate Haridatta's patron Jagatsiṃha. The compound *jagad-bhūṣana* can be read simultaneously to convey the distinction of the text and the prestige of the patron who commissioned it. The first reading—'ornament (*bhūṣana*) of the world (*jagat*)'—singles out the work as being extra-ordinary. The second reading—'ornament of/for Jagat[siṃha]'—is a lavish tribute to Jagatsiṃha himself and acknowledges his role in the origination of this text.[2] Furthermore, the epoch of the text is set in *Śaka* 1560 (1638 CE), a date which appears to have been deliberately chosen to further acknowledge Jagatsiṃha's patronage: the epoch falls exactly ten years after Jagatsiṃha's accession to power.[3]

Astronomical data in the *Jagadbhūṣaṇa* is structured according to the so-called cyclic format, a scheme in which true longitudes of the planets are computed and tabulated over large intervals of time. In these multi-year intervals—that vary from planet to planet—both the planet and its anomaly complete an integral number of revolutions (or very close to it). Once a cycle is completed, the planet returns to (almost) the same circumstances as at the beginning of the cycle, and thus the numerical data can be reused. Although substantial computation was involved to prepare the tabular data, from a table-user's point of view, the compilation of the annual calendar (*pañcāṅga*) was considerably simpler using this

1 For manuscript surveys and preliminary studies on this work, see Pingree (1968: 55–59), Pingree (1970: 104), Pingree (1973: 141–142), Pingree (1978: 319–320), Pingree (2003: 83–87), Montelle (2014), Montelle and Plofker (2018: 68–69, 116–118, 235–240, 254). This contribution is the first in a series which analyses this work, chapter by chapter, and is based on the doctoral thesis of Melnad (2018).

2 This second reading is based on the interpretation of the compound as: *jagatsiṃhasya ādeśat, nirmitaṃ bhūṣanam* ('as per the direction of Jagatsiṃha, the ornament is created') or *jagatsiṃham alaṅkartum nirmitaṃ bhūṣanam* ('an ornament created to embellish Jagatsiṃha').

3 There are likely compelling astronomical reasons for selecting this date as well. The astronomical significance of the epoch positions and circumstances remains to be studied more fully.

table text, since the tables themselves provide true longitudes and motions of the planets directly. This is unlike other historical tabular formats, in which the user had to consult tables of mean planetary data and then tables of their orbital corrections and combine the resulting multiple numerical values accordingly. Another advantage of such a format is that cyclic tables are perpetual in design; in principle, they can be used for any date whatsoever from the epoch (typically, with some minor adjustments for each completed cycle).

This format appears to have been popular in other earlier cultures of inquiry and finds its roots in the so-called Goal Year Periods of Babylonian mathematical astronomy (Pingree 1970: 104). Cyclic schemes also feature in Greek and Arabic sources, notably in Ptolemy's *Almagest* and the Islamicate Almanacs of al-Zarqālī. Table 1 presents the length of these large cycles for each of the planets in various historical sources, along with Haridatta's scheme.

Planet	Babylonians (312–63 BCE)	Ptolemy (100–170 CE)	al-Zarqālī (1029–1087 CE)	Haridatta (1638 CE)
Mars	79	79	79	79
Mercury	46	46	46	46
Jupiter	71	71	83	83
Venus	8	8	8	227
Saturn	59	59	59	59

Table 1: Large astronomical planetary cyclic periods in years from various sources (as compiled by Pingree (1968: 56)).

One of the earliest instances where we find the use of cyclic periods in Indian astronomy is in Vararuci's *candravākyas* (lit. 'moon sentences'), a set of 248 mnemonics specifying the true longitudes of the moon.[4] A later text, the *Vākyakaraṇa* ('A manual [for constructing] *vākyas*') includes similar versified tabulated data, but for all the planets. Haridatta's work is a far more elaborate table text of this sort—the numerical data was certainly not meant to be memorised! His cyclic periods are large and densely populated with astronomical data for a novel time interval, the *avadhi*, a 14-day period. In addition to true longitudes, Haridatta also tabulates the rate of motion of the planets and their synodic phenomena.

The impact that Haridatta's cyclic tables had as a genre on Indian astronomy is difficult to fully ascertain. We are not sure if it ever became a popular genre

4 These were composed perhaps around the fourth century CE (Sarma and Subbarayappa 1985: 48).

in India. Only one other cyclic table text is known—a work by Trivikrama composed around 1704.[5] Perhaps the enormous computational effort required to produce these tables was enough of a disincentive for astronomers to undertake composing such tables of their own. Nevertheless, Haridatta's work was prodigious and set new standards in tabular data in the Indian astral sciences.

AN OVERVIEW OF THE TEXT AND TABLES IN THE *JAGADBHŪṢAṆA*

Haridatta explicitly associates the epoch of the *Jagadbhūṣaṇa* to the accession to power of Jagatsiṃha (verse 1.17):

> When that [current *Śaka* year] is diminished by 1550, [there results] the regnal *Śaka* years of Jagatsiṃha, the ruler of the world. [That further] diminished by 10 [gives] the count of years [elapsed] since the composition of the text.

The epoch year *Śaka* 1560 corresponds to 1638 CE. In that year, the beginning of the solar year (i.e., *Meṣasaṅkrānti*) occurred on Thursday, April 8.[6] This weekday being Thursday is confirmed by data found in the numerical tables of this work (see section 3).

Numerical data in the text[7] reveal that these tables pertain to a latitude of $\phi \approx 24^{\circ}$N. Given the broader context of this work, the association with the royal lineage of Jagatsiṃha and the accolades expressed for the city of Udaipur (verse 1.5), we surmise that these tables were indeed intended for the location of Udaipur, one of the major cities in the Mewar region of Rājasthān.[8]

The *Jagadbhūṣaṇa* has many of the features typical of a *karaṇa*/handbook astronomical work, although Haridatta does not identify it as such. The five chapters cover almost all major topics in astronomy; Table 2 lists the titles of each chapter along with the number of verses in each.

Chapters one and two of the *Jagadbhūṣaṇa* cover the determination of the position and daily motions of the sun, the moon, the moon's anomaly, and the five

5 For details, see Pingree (1978: 320), Pingree (1968: 64–65), Pingree (1970: 104), Pingree (1970–94: A3, 92b–93b and A4).

6 This date was confirmed by Yano (2004) and Drikpanchang (2023). Pingree (1968: 56) proposed this epoch date as Saturday, 31 March 1638. However, we are not able to reconstruct Pingree's reasoning for this dating; but it could be related to the use of the Julian calendar.

7 Numerical entries from a length of daylight table and associated scribal paratext in MS **P** (f. 99v) indicate the length of the longest day for the locality of the tables is 33;48 *ghaṭikās*. From this, the terrestrial latitude can be reconstructed using the relationship between the ascensional difference $\Delta\alpha$, solar declination δ and terrestrial latitude ϕ via: $\sin\Delta\alpha = \tan\phi\tan\delta$.

8 In a previous synopsis of the tabular data made by Pingree (1968: 57), Ujjain is proposed as the location, a city whose latitude varies from that of Udaipur only by roughly one degree. However, we argue Udaipur is a more appropriate location both astronomically and contextually.

Sanskrit chapter title	English equivalent	No. of verses
Sūryacandrasphuṭīkaraṇaṃ	Obtaining the true positions of the sun and moon	36
Bhaumādisphuṭīkaraṇaṃ	Obtaining the true positions of Mars and so on	10*
Lagnādivimiśraṃ	Miscellany on the ascendant, etc.	24
Grahaṇaṃ	Eclipse	34
Pañcāṅgasphuṭīkaraṇaṃ	Obtaining the accurate calendar	28

Table 2: An overview of the chapter of the *Jagadbhūṣaṇa* (*This chapter also contains a number of short prose passages at the end).

star-planets via the tables. It is these two chapters which pertain most directly to the numerical tables. Table 3 lists the titles of the tables and their contents as set out in MS **P**.

Chapter three covers astronomical phenomena related to the so-called 'three questions', namely those related to direction, location and time. This chapter includes rules for determining the ascendant, rising times, declination, local terrestrial latitude, ascensional difference, and the helical rising and setting of Agastya. It also includes a versified sine table with Radius $R = 90$. Chapter four presents the standard procedures for eclipse reckoning. Chapter five covers detailed rules for determining aspects of the calendar, including *tithi*s, *yoga*s, and *nakṣatra*s. This chapter appears to have many parallels with the sixteenth-century calendrical work, the *Tithicintāmaṇi* of Gaṇeśa Daivajña.

OVERVIEW OF THE MANUSCRIPTS

The following manuscripts were consulted for this study:

MS **B**: BORI 399 of 1899–1915, Bhandarkar Oriental Research Institute, Pune.
MS **J**: Khasmohor 5420, Jaipur Palace Library, Jaipur.
MS **L**: LDI 6182, Lalabhai Dalpatabhai Institute of Indology, Ahmedabad.
MS **P**: Poleman 4869 (Smith Indic 146), Rare Books and Manuscript Library, Columbia University, New York.

The first three contain the text of the *Jagadbhūṣaṇa* only; the fourth contains only the tables of the *Jagadbhūṣaṇa*. We are not aware of the existence of any manuscripts that contain both the text and a complete set of the tables.

No.	Sanskrit table title	Contents of the table	Location
1.	भौमस्पष्टः	True longitudes and rates of motion of Mars (for 79 years)	ff. 1v–21r
2.	श्रीबुधपङ्क्तयः	True longitudes and rates of motion of Mercury (for 46 years)	ff. 22r–33v
3.	गुरुस्पष्टः	True longitudes and rates of motion of Jupiter (for 83 years)	ff. 34r–47v
4.	भृगुपङ्क्तयः	True longitudes and rates of motion of Venus (for 227 years)	ff. 48r–85v
5.	शनिपङ्क्तयः	True longitudes and rates of motion of Saturn (for 79 years)	ff. 86r–95v
6.	सचक्रप्रतिवर्षम् अब्दपकोष्ठकाः	Table pertaining to lord of the year (values in days etc., for 89 years)	f. 96r
7.	प्रतिवर्षं शुद्धिकोष्ठकाः	Table pertaining to epact (values in *tithi*s etc., for 122 years)	ff. 96v–97r
8.	प्रतिवर्षं चन्द्रकोष्ठकाः	Mean lunar position (for 122 years)	ff. 97r–97v
9.	प्रतिवर्षं केन्द्रकोष्ठकाः	Values of the lunar anomaly at the beginning of the year (for 43 years)	ff. 97v–98r
10.	प्रत्यवधि चन्द्रचालको राश्यादिः	Displacement of the moon (for 27 *avadhi*s)	f. 98r
11.	प्रत्यवधि केन्द्रचालको राश्यादिः	Displacement of lunar anomaly (for 27 *avadhi*s)	f. 98r
12.	प्रतिदिनं चन्द्रचालको राश्यादिः	Displacement of the moon per day (for 1 to 13 days)	f. 98r
13.	प्रतिदिनं केन्द्रचालको राश्यादिः	Displacement of the lunar anomaly per day (for 1 to 13 days)	f. 98v
14.	प्रति घटिकां चन्द्रचालको अंशादिः	Displacement of the moon per *ghaṭī* (for 1 to 60 *ghaṭī*s)	f. 98v
15.	केन्द्रभुजत्र्यंशात् प्रत्यंशं चन्द्रस्य मन्दफलम् अन्तरं गत्यन्तरं च	Table of lunar equations for 30 arguments with rates of motion and their differences	f. 99r
16.	स्वदेशसूर्योदयकालानयनसंस्कारः	Corrections pertaining to obtaining the true sunrise time at a given location	f. 99r
17.	प्रत्यवधि सूर्यस्पष्टः	True longitudes of the sun with rate of motion (for 27 *avadhi*s)	f. 99v
18.	दिनमानम्	Length of day for each of the 27 *avadhi*s	f. 99v
19.	प्रतिवर्षं राहुकोष्ठकाः	Mean motion of the lunar node for 93 years	f. 100r
20.	प्रत्यवधि राहुकोष्ठकाः	Mean motion of the lunar node for 27 *avadhi*s	f. 100v
21.	सौरसङ्क्रान्तिकोष्ठकाः	Solar transits in 12 zodiac signs and 27 *nakṣatra*s	f. 100v

Table 3: An outline of the contents of the tables of the *Jagadbhūṣaṇa* found in MS **P**: Poleman 4869 (Smith Indic 146) (Columbia University, Rare Book and Manuscript Library, New York), 100 ff. In presenting the Sanskrit title of the tables, we have made certain minor modifications for maintaining consistency as well as fixing scribal errors. We have also introduced titles that were absent in certain tables.

*MS **B**: BORI 399 of 1899–1915, Bhandarkar Oriental Research Institute (BORI), Pune, 4 ff.*

Available to us in a black-and-white photocopy. This copy is neatly written. 18 lines per page. The scribe has written जगद्भूषणसूत्र (*jagadbhūṣaṇasūtra*) on several folia in the top-left margin. Corrections and scribal notes appear in the margins. No date is mentioned. An image of the first page can be seen in Figure 1.

*MS **J**: Khasmohor 5420, Jaipur Palace Library, Jaipur, 7 ff.*

Available to us in a color photocopy. 11 × 26.5 cm (Pingree 2003: 84). The script is compact but legible. 12 lines per page. Corrections have been made using yellow paste. The colophon on f. 7v reads इति श्रीगणकचक्रचूडामणिभट्टश्रीहरजी ० महारा ० पंचम ॥५॥. The date of copying is found as a post-colophon on f. 7v: संवत् १८२६ आषढे कृष्णे तिथौ ९ बुधे लिपीकृतम् (Saṃvat 1826, Āṣāḍha, dark fortnight, 9th *tithi*, Wednesday), corresponding to Wednesday 28th of June, 1769 CE. An image of the first page can be seen in Figure 2.

*MS **L**: LDI 6182, Lalabhai Dalpatabhai Institute of Indology, Ahmedabad, 5 ff.*

Available to us in a black-and-white photocopy. The script is very neat. 15 lines per page. The date of copying is found on f. 5v: श्रीरस्तुः संवत् १७१७ वर्षे पौषमासे शुक्लपक्षे २ तिथौ रविवासरे । (Saṃvat 1717, Pauṣa, bright fortnight, 2nd *tithi*, Sunday), corresponding to Sunday 2nd January, 1661 CE . An image of the first page can be seen in Figure 3.

*MS **P**: Poleman 4869 (Smith Indic 146), Rare Books and Manuscript Library, Columbia University, New York, 100 ff.*

Available to us in black-and-white photocopy. Ruled numerical tables only. While the majority of this manuscript is legible, there are several places especially on the left and right margins where characters and portions of text are smudged or blackened out. Around 14 to 21 table rows per page. The date of the manuscript is not recorded. The title of the manuscript is found on f. 1r: जगद्भूषणसंज्ञकस्य ज्योतिर्ग्रन्थस्य कोष्टकानि (*jagadbhūṣaṇasaṃjñakasya jyotirgranthasya koṣṭhakāni*). The scribe has also noted श्लोक ३००० (*śloka 3000*) which may be an attempt to quantify the magnitude of the copying task. A sample image of a page of numerical tables can be seen in Figure 4.

METRICAL FEATURES OF THE *JAGADBHŪṢAṆA*

While some of the important early works on Indian astronomy, such as the *Āryabhaṭīya* and the *Brāhmasphuṭasiddhānta*, adopt only one meter throughout their composition, Haridatta has employed a variety of meters in the *Jagadbhūṣaṇa*.

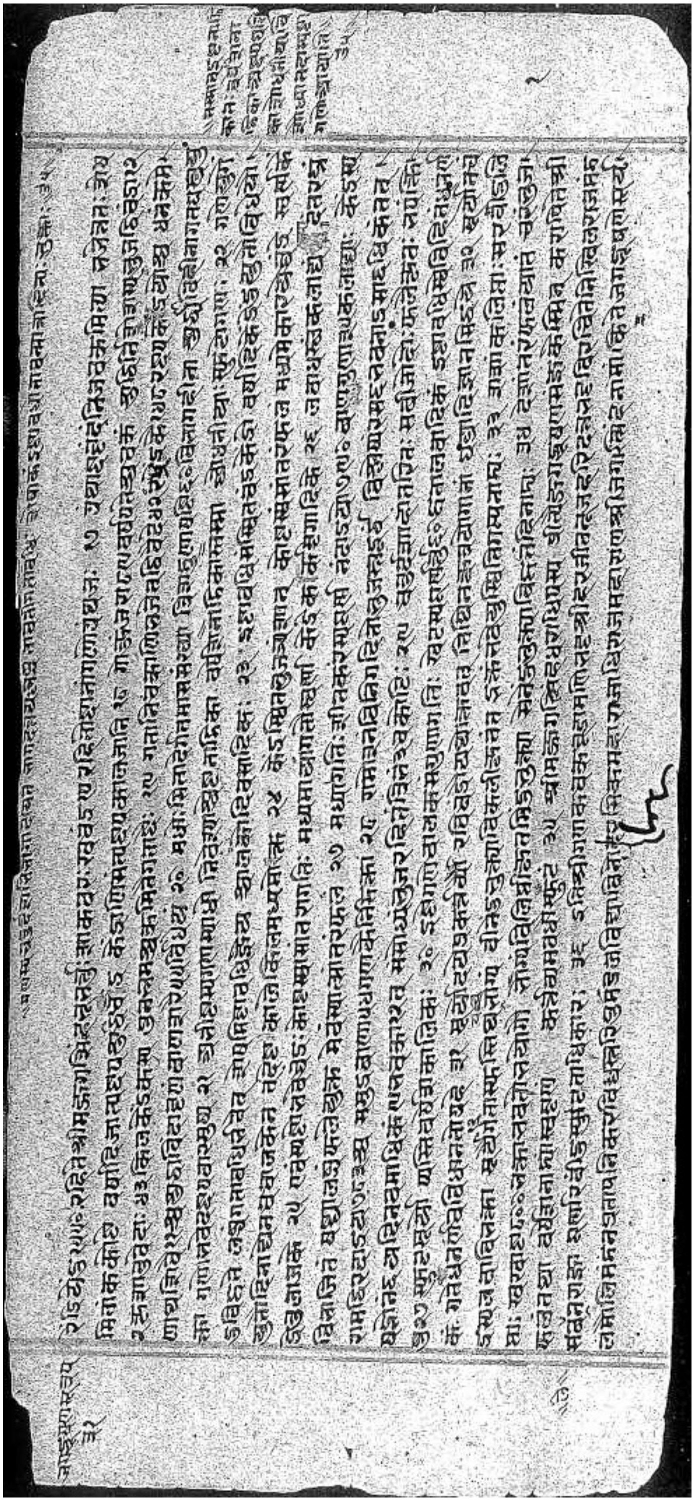


Figure 1: Sample image of MS **B** showing its general palaeographic features.

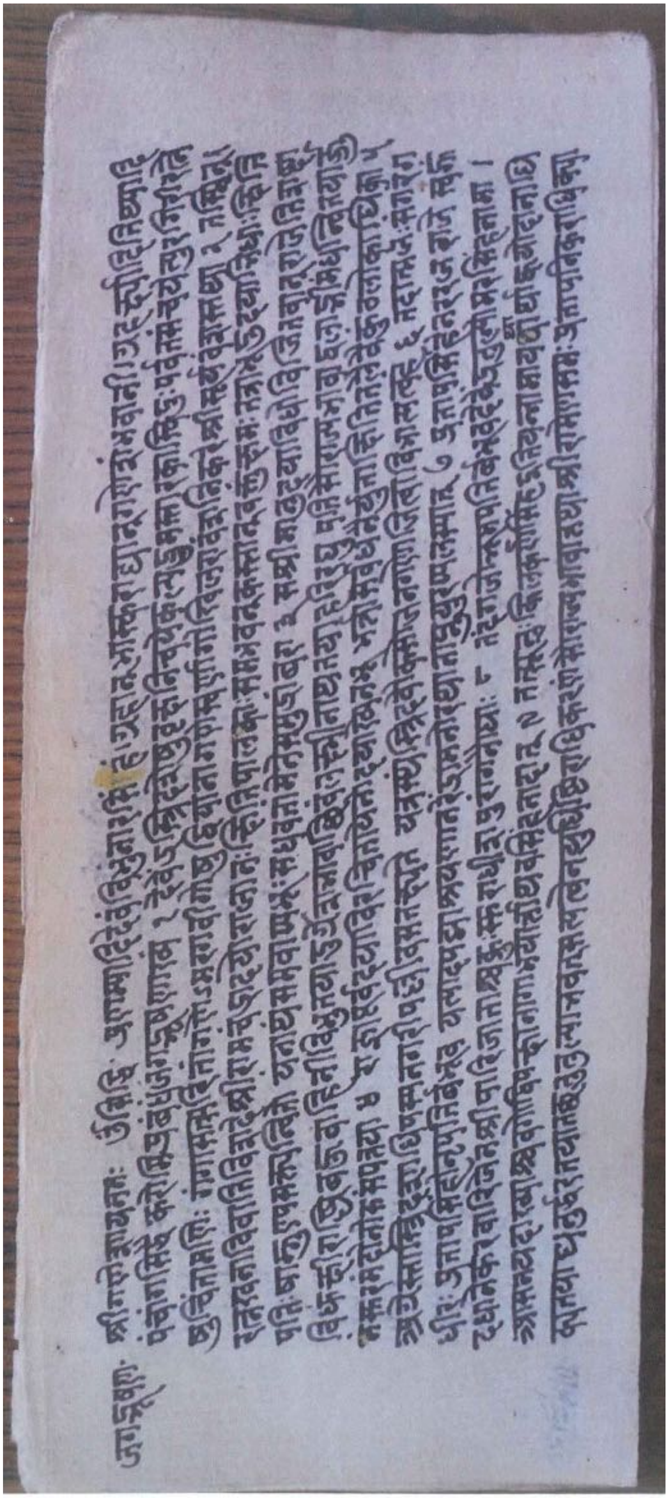


Figure 2: Sample image of MS **J** showing its general palaeographic features.

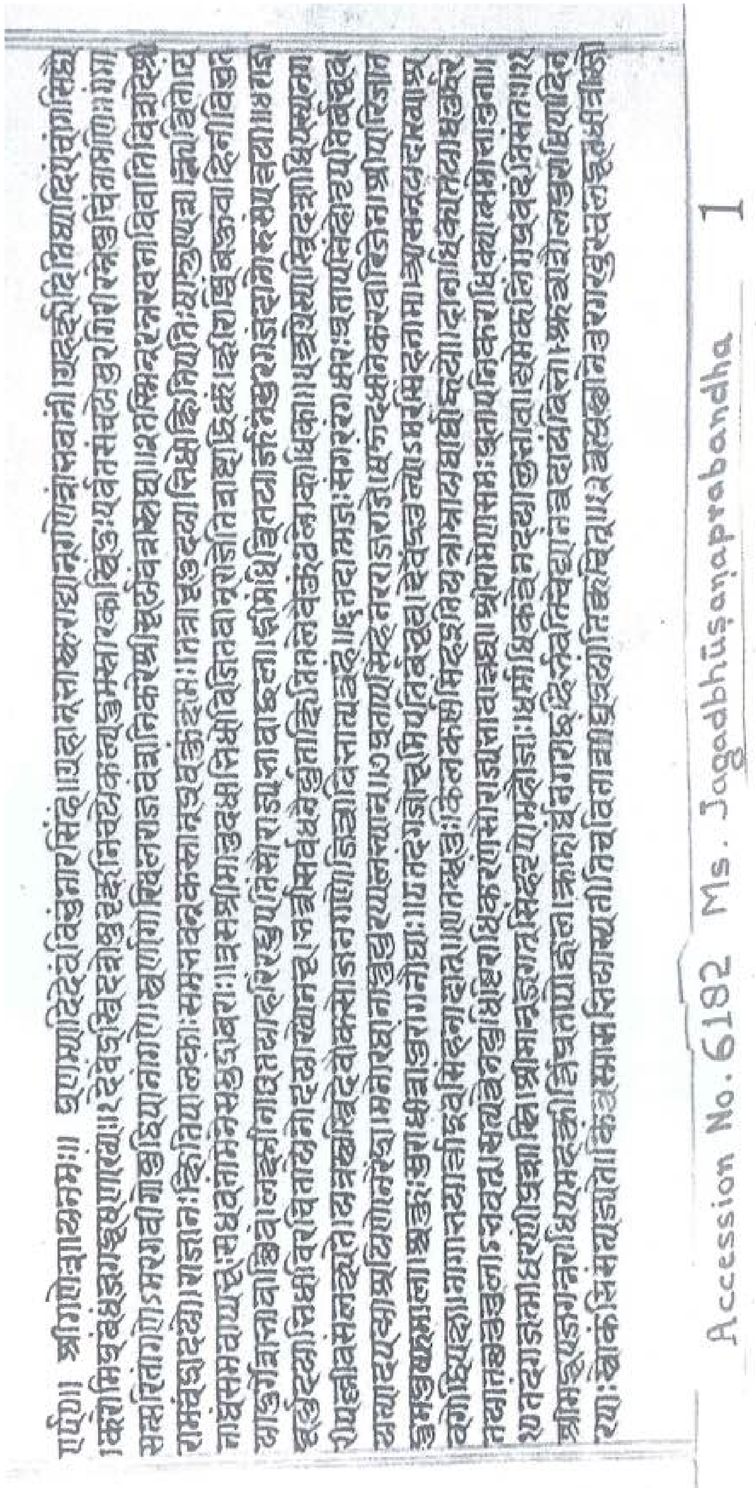


Figure 3: Sample image of MS **L** showing its general palaeographic features.

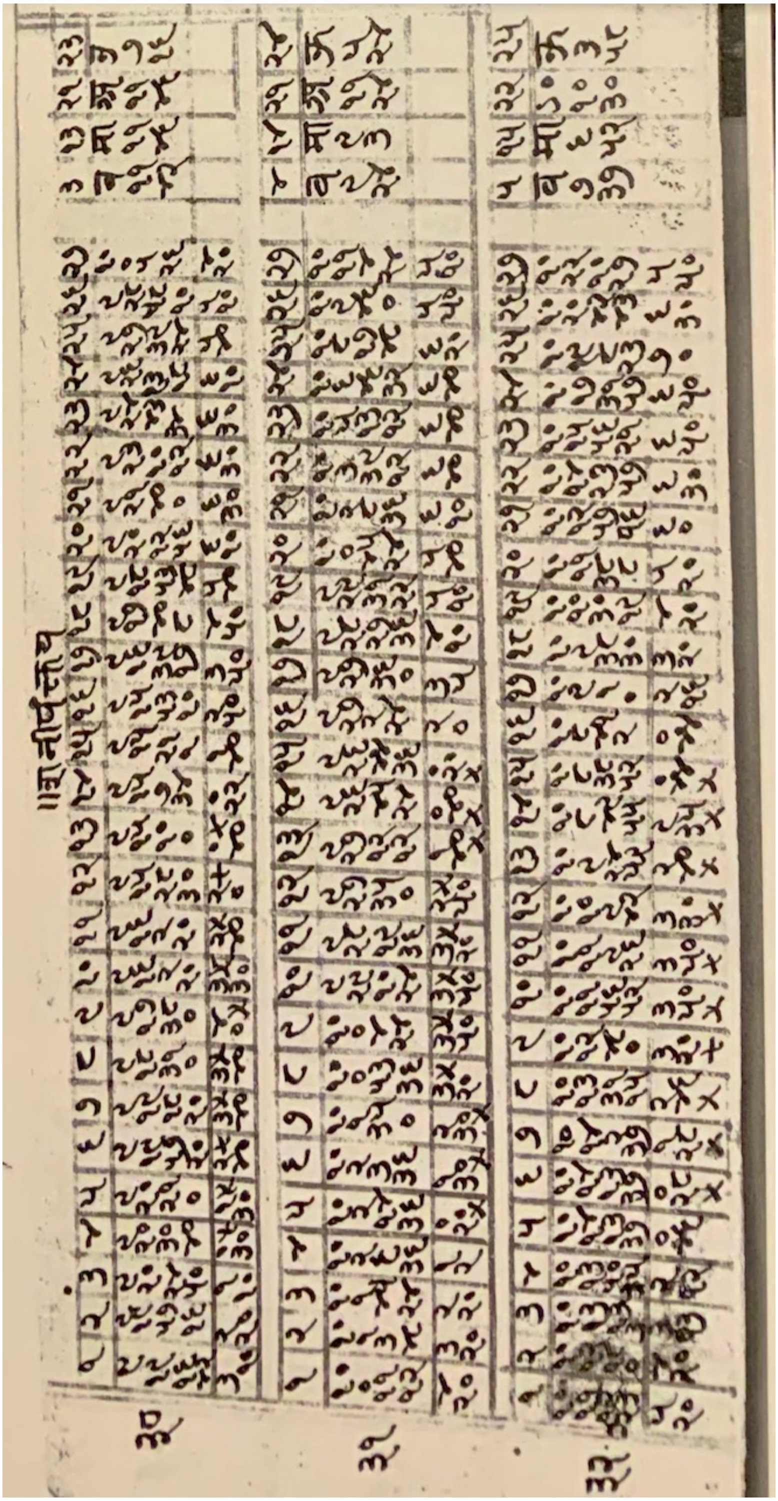


Figure 4: Sample image of MS **P** showing its general palaeographic features and tabular grids.

Meter (*vṛtta*)	No. of Verses
Anuṣṭup	35
Āryā	1
Indravajrā	14
Upajāti	46
Upendravajrā	1
Citralekhā	1
Puṣpitāgrā	1
Pramāṇikā	1
Praharṣiṇī	1
Bhujaṅgaprayāta	3
Mālinī	1
Rathoddhatā	2
Vasantatilakā	2
Vāsantikā	1
Śārdūlavikrīḍita	13
Śālinī	7
Svāgatā	2
	132

Table 4: A summary of the meters employed by Haridatta in the *Jagadbhūṣaṇa*.

Perhaps this was to enhance the charm of his composition, and make the text more appealing.[9] In Table 4, we provide the names of meters along with the number of verses composed in that meter in the *Jagadbhūṣaṇa*. Among the most frequent metres are *Upajāti* and *Anuṣṭup*, but other more elaborate or rare metres appear throughout, including *Śārdūlavikrīḍita*, *Pramāṇikā*, *Puṣpitāgrā* and *Vāsantikā*.

2 AN OVERVIEW OF CHAPTER ONE OF THE *JAGADBHŪṢAṆA*

HARIDATTA WAS WORKING during a pivotal moment in north Indian history. The relations between the Sisodia clan of Rajputs of Mewar and the much larger Mughal empire were complex. From the late sixteenth until the early

9 Using a variety of poetic metres is usually employed purposefully by an author. Some later texts predominantly stick to a single meter, such as the *Tantrasaṅgraha* of Nīlakaṇṭha or the table text *Candrārkī* of Dinakara.

seventeenth century, the Sisodias were frequently under attack from Mughal forces. Eventually however by the mid seventeenth century, the Sisodias accepted Mughal suzerainty and relations between the Rajputs and Mughal emperors appear to have been increasingly harmonious. At a certain point, the Mughal emperor Shāh Jahān (ruled 1628–1666) granted the Sisodias semi-autonomous statehood.

With the constant presence of the Mughal empire, Mewar rulers appeared eager to maintain aspects of their political and cultural identity. They sought to achieve this in part through the arts and sciences. These disciplines served as platforms for celebrating the cultural origins of the Rajput dynasty. Modern scholars have noted this in architecture and the visual arts of this period. Art theorist Jennifer Joffee (2005: 58–83) argues convincingly for the omnipresence of this aspiration in art and architecture during this time. She singles out the use of archaic elements which served to venerate and emphasise the cultural roots of the Sisodias. In a similar vein, art historian Melia Bose (2015: 251) notes that artists and scholars of this period would 'self-consciously draw from the artistic traditions of the pre-Mughal past' and would 'create markedly different artworks that communicated their cultural distance from the Mughals'.

Jagatsiṃha ascended to power amidst extended periods of peace which brought with them prosperity and, in turn, renewed spending on the arts and sciences. He is well-known for his generous patronage (Bose 2015: 272) in these areas. Alongside his substantial patronage of art and architecture (Bose 2015: 256), Jagatsiṃha commissioned literary and scientific works as well. Among these included Haridatta's treatise on mathematical astronomy, the *Jagadbhūṣaṇa*. This composition too in many ways can be seen to epitomise this new emphasis on cultural distinction.

FEATURES OF THE ENCOMIUM

In addition to the technical astronomical content, the work has been used as a platform for promoting the glory of the Sisodia dynasty. The *Jagadbhūṣaṇa* includes a lengthy encomium at the beginning of the work which celebrates the lineage and status of the Sisodian clan in a passage which occupies almost a sixth of the entire work. Uncovering such details from the opening verses of the *Jagadbhūṣaṇa* thus contributes to growing scholarly evaluations of artistic and intellectual endeavours at the Mewar courts and bear witness to the circumstances in which scholars worked during this period.

Beginning from the *Sūryavaṃśa*, the legendary Solar dynasty, from which the Sisodia dynasty claim their origins, Haridatta surveys the various *mahārāṇā*s pivotal to the rise of Jagatsiṃha and gives an embellished account of their qualities and achievements. Figure 5 lists the lineage of *mahārāṇā* s that Haridatta

Sanskrit name	Modern name	Dates (CE)
Udayasiṃha	Udai Singh II	1540–1572
Pratāpasiṃha	Pratap Singh I	1572–1597
Amarasiṃha	Amar Singh I	1597–1620
Karṇasiṃha	Karan Singh II	1620–1628
Jagatsiṃha	Jagat Singh I	1628–1652

Table 5: The lineage of *mahārāṇā* s of the Sisodia dynasty leading up to Jagatsiṃha.

refers to in the encomium during the mid-sixteenth and first half of the seventeenth century. From the *mahārāṇā* Udayasiṃha, Haridatta proceeds from father to son in turn over a number of verses until he reaches Jagatsiṃha, his patron.

Besides other things, the encomium is notable for its flair and poetic beauty, achieved through the use of artistic literary embellishments known in Sanskrit as *alaṅkāra*.[10] The generous praise contained in these verses is amplified by conventional poetic effects including simile (*upamā*), metaphor (*rūpa*ka), nuanced forms of double readings and puns (*śleṣa*), exaggeration (*atyukti*), and poetic sound effects such as assonance (*vṛtyanuprāsa*), consonance (*yamaka*) and alliteration (*chekānuprāsa*). Haridatta weaves in familiar mythological references to further amplify the status and sovereignty of this lineage. The effect of this is to impress upon those that used this text the profound and glorious reign of Jagatsiṃha. This memorable celebration of the Sisodia dynasty thus provides a fitting context for Haridatta's astronomical work to begin.[11]

CONTENTS OF CHAPTER ONE

The first chapter of the *Jagadbhūṣaṇa* covers the determination of the true longitudes and daily motions of the sun and the moon, and from these, related phenomena. We present below a list of topics included in this chapter:

- **Verse 1**: Invocation
- **Verses 2–16**: Encomium
- **Verse 17**: Specifying the epoch as *Śaka* 1560 (1638 CE)

10 A study of the use of *alaṅkāra* in scientific treatises have been the subject of some previous studies (Misra et al. 2016; Ramasubramanian, Kolachana, et al. 2018), but such analyses are still emerging as an important aspect of these technical treatises.

11 A preliminary analysis and translation of the encomium only appear in Melnad et al. (2019).

- **Verses 18–20**: Listing the cyclic periods (*cakra*) for the 'lord of the year' (*abdapa*), epact (*śuddhi*), lunar longitude, and the lunar anomaly (*kendra*) and how to determine their current amounts via the accompanying tables and their residual corrections.
- **Verses 21–22**: Describing the procedure for converting lunar days (*tithis*) into civil days (*ahargaṇa*) from the beginning of the solar year.
- **Verse 23**: Calculating the appropriate tabular argument in *avadhis* (a period of 14-days) and a remainder (*cālaka*) to select the appropriate data from the tables.
- **Verse 24**: Obtaining the mean position of the moon and its anomaly.
- **Verses 25–27** Determining the true longitude of the moon using the eccentricity correction (*mandaphala*) table and an interpolation algorithm.
- **Verse 28** Specifying the mean daily motion of the moon and its anomaly.
- **Verse 29**: Reducing arcs to the first quadrant and the definition of the complement.
- **Verses 30–31**: Determining the true longitude of the sun and its daily motion using a single table.
- **Verse 32–34**: Computing calendrical luni-solar time-units such as the elapsed *tithi*s, *nakṣatra*s and *yoga*s on a desired day and determining when the current ones will end.
- **Verse 35**: Establishing the instant of true local sunrise using the four time corrections: the *deśāntara*, the *yātaphala* (also known as *udayāntara*), *cara* (ascensional difference), and the *bhujaphala*.
- **Verse 36**: Closing remarks.

While the *Jagadbhūṣaṇa* shares many features of a conventional astronomical handbook, it diverges from this format in significant ways. Indeed, occasionally parameters are provided directly (such as the mean motion of the moon and its anomaly), but the majority of the chapter focuses on procedures for retrieving the required numerical data from the tables. This represents a notable shift from the standard astronomical texts in which various planetary parameters are listed in the text, along with algorithms to compute the phenomena in question. In a table text, these features are redundant as all relevant data has been precomputed.

3 TEXT, TRANSLATION, AND ANALYSIS OF THE VERSES

In what follows, we present an edited version of the first chapter of the *Jagadbhūṣaṇa* in *Devanāgarī* and Roman transliteration, along with an English translation.[12] This is followed by a detailed analysis of the historical, technical and

12 A critical edition of this text is forthcoming.

astronomical content of the verses. Where the text refers to a table, we have provided an image of that table from MS **P** along with a diplomatic transcription of the numerical values. We have not attempted to correct any values, even when they appear to be obviously erroneous. While we have analysed the tabular data in a broad sense, we leave the recomputation and reconstruction of specific tabulated values for future studies.

INVOCATION AND PURPOSE OF THE WORK

मङ्गलाचरणं ग्रन्थप्रयोजनञ्च

श्रीगणेशाय नमः ॥
Homage to Lord Gaṇeśa.

> **प्रणम्यादिदेवं विभुं नारसिंहं**
> **ग्रहान् भास्कराद्यान् गणेशं भवानीम् ।**
> **ग्रहर्क्षादितिथ्यादिपञ्चाङ्गसिद्ध्यै**
> **करोमि प्रबन्धं जगद्भूषणाख्यम् ॥ १ ॥** **[भुजङ्गप्रयातम्]**
>
> *praṇamyādidevaṃ vibhuṃ nārasiṃhaṃ*
> *grahān bhāskarādyān gaṇeśaṃ bhavānīm |*
> *graharkṣādititihyādipañcāṅgasiddhyai*
> *karomi prabandhaṃ jagadbhūṣaṇākhyam* ||1|| [*bhujaṅgaprayātam*]
>
> Having bowed to Narasiṃha, who is the foremost deity [and] the all-pervasive, [and] the planets beginning with the Sun (Bhāskara II), Gaṇeśa, [and] Bhavānī, I compose the treatise (*prabandha*) called *Jagadbhūṣaṇa* for the determination of [the positions of] the planets, *nakṣatra*s, *tithi*s and so on for [the purpose of] obtaining a *pañcāṅga*.

Following the standard convention, Haridatta commences the *Jagadbhūṣaṇa* with an invocatory verse (*maṅgalācaraṇa*). This is generally in the form of offering veneration to teachers or salutations to one's own deities. First, Haridatta pays reverence to Narasiṃha, who is described as the 'foremost deity' (*ādideva*). Then given the astronomical significance of the text, he offers his veneration to the planets. Lastly, he pays homage to Gaṇeśa and Gaṇeśa's mother, Bhavānī.

In the second half of this verse, Haridatta states the name of the work. He refers to it as a *prabandha* (lit. 'composition'), a generic term typically used for a treatise. Indeed, the emphasis in the work is on simplicity and ease of use, and the tone and scope of the work is closest to that of the *karaṇa* (handbook) genre. But given the substantial number of numerical tables that accompany the text, this treatise takes on new significance beyond the canonical *karaṇa*. Haridatta reveals the purpose of the text is the computation of the positions of planets, stars, *tithi*s etc., for constructing the annual *pañcāṅga*. Here, by the Sanskrit suffix *ādi* found in the phrase *tithyādi*, Haridatta is implying the five elements of *tithi*, *vāra*, *nakṣatra*, *yoga* and *karaṇa* which together form the basis of a *pañcāṅga*. In addition, the suffix *ādi* in the compound *graharkṣādi* implies instances of eclipses, *muhūrtas* etc., and other astronomical events that are recorded in a *pañcāṅga*.

THE GLORY OF THE SOLAR DYNASTY

सूर्यवंशमहिमा

देवेन्द्रस्त्रिदशेषु वृक्षनिचये कल्पद्रुमस्तारका-
स्विन्दुः पर्वतसञ्चये सुरगिरी रत्नेषु चिन्तामणिः ।
गङ्गा सत्सरितां गणेऽमरगवी गोषु द्विपानां गणे
स्वर्णागोऽखिलराजवंशनिकरे श्रीसूर्यवंशस्तथा ॥ २ ॥ [शार्दूलविक्रीडितम्]

devendrastridaśeṣu vṛkṣanicaye kalpadrumastārakā-
svinduḥ parvatasañcaye suragirī ratneṣu cintāmaṇiḥ |
gaṅgā satsaritāṃ gaṇe'maragavī goṣu dvipānāṃ gaṇe
svarṇāgo'khilarājavaṃśanikare śrīsūryavaṃśas tathā ||2||

[*śārdūlavikrīḍitam*]

As Indra (*Devendra*) amongst the Gods, the wish-yielding tree (*kalpadruma*) amidst groves of trees, the moon amongst stars, Meru (*suragiri*) amongst the mountains, the wish-yielding gem (*cintāmaṇi*) amongst the various precious stones, Gaṅgā amongst the multitude of perennially flowing rivers, Kāmadhenu (*amaragavī*) amongst herds of cows, Airāvata (*svarṇāga*) amongst herds of elephants, so too is the great solar dynasty (*Śrī Sūryavaṃśa*) amongst the multitude of dynasties.

After the traditional invocatory verse, Haridatta embarks on a lengthy encomium, dedicated to praising the glory of the lineage of Jagatsiṃha. He begins by invoking the legendary solar dynasty (*Sūryavaṃśa*),[13] thus setting the backdrop for the Sisodia dynasty which finds its origins in this celebrated line. To emphasise the significance of the *Sūryavaṃśa*, Haridatta employs a series of similies (*upamā*). Not being content with one or two similes, Haridatta here presents eight different scenarios, and singles out the supreme element in each. The *Sūryavaṃśa* dynasty is then compared to the epitome of each group. This poetic act of comparison richly conveys the superiority and status of this dynasty.

13 For a detailed description of the solar dynasty, see Kālidāsa's *Raghuvaṃśa* (Parab and Paṇśīkar 1925: esp. chapter 1, verses 5–12).

MAHĀRĀṆA UDAYASIṂHA

The Birth and the Glory of the Emperor Udaya

उदयमहाराजस्य जन्म तन्महिमा च

तस्मिन् रत्नखनाविवातिविशदे श्रीरामचन्द्रादयः
राजानः क्षितिपालकाः समभवन् कस्तान् प्रवक्तुं क्षमः ।
तत्राभूदुदयाभिधो क्षितिपतिः षाड्गुण्यशक्त्यन्वितः
यं नाथं समवाप्य भूः सभवतां मेने समुद्राम्बरा ॥ ३ ॥ [शार्दूलविक्रीडितम्]

tasmin ratnakhanāvivātiviśade śrīrāmacandrādayaḥ
rājānaḥ kṣitipālakāḥ samabhavan kas tān pravaktuṃ kṣamaḥ |
tatrābhūdudayābhidho kṣitipatiḥ ṣāḍguṇyaśaktyanvitaḥ
yaṃ nāthaṃ samavāpya bhūḥ sabhavatāṃ mene samudrāmbarā ||3||

[*śārdūlavikrīḍitam*]

In that vast and expansive [dynasty] which is comparable to a mine of gems, there were kings like Śrī Rāmacandra who were protectors of the whole earth. Who is capable of describing them (i.e., their glory, etc.)? There [in this dynasty] arose a king Udaya by name, possessed of the six qualities, by obtaining whom as lord, the Earth, who has the ocean as [her] garment, considered the purpose of her existence to be fulfilled.

Having established the roots of Sisodia lineage in the legendary *Sūryavaṃśa* dynasty, Haridatta jumps to the more recent past, to a king called Udaya. From the name of the successors given in the next few verses, it is evident that Haridatta is referring to Udai Singh II, Mahārāṇa of the Mewar kingdom whose reign was from 1540–1572 CE. Carrying on the same figure of speech, namely *upamā*, employed in the previous verse into this verse as well, Haridatta compares the kings of the *Sūryavaṃśa* to precious gems in a mine, implying a similar comparison for Udaya.

Despite his admission of the difficulties of capturing Udaya's glory in words, Haridatta nevertheless continues with accolades of praise over several verses. Firstly, to convey Udaya's greatness as a king, Haridatta ascribes to him six regal qualities.[14] Next, Haridatta closes this verse with a beautiful metaphor captured by the *bahuvrīhi* compound *samudrāmbarā* 'the one who has the ocean as [her] garment'. This phrase is an epithet to the earth which forms a striking example of the figure of speech known as *rūpa*ka (metaphor).

14 Though these qualities themselves are not mentioned here explicitly, they appear to refer to a set of six traits that can be found in chapter 7, verse 160 of *Manusmṛti* (Dave 1972–84: v. 4, 125): *sandhi*, *vigraha*, *yāna*, *āsana*, *dvaidhībhāva*, and *saṃśraya*.

Multiple Virtues of King Udaya

उदयस्य नैकगुणगानम्

स श्रीमानुदयाभिधो विजितवान् राजेति शब्दाधिकं
क्षीराब्धिं बहुवाहिनीविभुतया दुर्गेशभावाच्छिवम् ।
लक्ष्मीनाथतया हरिं रघुपतिं सौराज्यभावाद्बलात्
भीमं धन्वितयार्जुनं सुरगजं दानोरुसंपन्नया ॥ ४ ॥ [शार्दूलविक्रीडितम्]

sa śrīmānudayābhidho vijitavān rājeti śabdādhikam
kṣīrābdhiṃ bahuvāhinīvibhutayā durgeśabhāvācchivam |
lakṣmīnāthatayā hariṃ raghupatiṃ saurājyabhāvādbalāt
bhīmaṃ dhanvitayārjunaṃ suragajaṃ dānorusaṃpannayā ||4||

[*śārdūlavikrīḍitam*]

He, Udaya by name, the possessor of varieties of wealth (*śrīman*), championed many other names [as titles] besides [the title of] king: ocean of milk, by virtue of being the lord of many rivers/armies; Śiva, being the lord of Durga/the fort; Hari, by virtue of being the lord of Lakṣmī/wealth; Raghupati (Rāma), by providing good governance; Bhīma, because of [his] strength; Arjuna, by virtue of being an [excellent] archer; [and] the heavenly elephant (*suragaja*), by virtue of possessing generosity in abundance (*uru*).

Here Udaya is personified as: the ocean, Śiva, Hari, Rāma, Bhīma, Arjuna, and the heavenly elephant. All of these associations are to highly acclaimed entities either because of their physical/mythical significance or because of their heroic deeds. By identifying Udaya with each of these names, Haridatta further exemplifies his qualities through a figure of speech that goes by the name *ullekha*.

Haridatta also incorporates many clever puns or *śleṣa* in this verse. Finally, Udaya is called the heavenly elephant, because of his virtue of possessing '*dānoru*', that is abundant generosity, or equally, abundant rut-fluid, a substance which elephants produce during the period of musth or elevated testosterone levels. In this way, the verse is filled with double-entendre which utilise the rich polysemy of Sanskrit.

The Birth of the City of Udaipur and its Glory

उदयपुरोदयः तत्पुरवैभवञ्च

राज्ञा पुर्युदयाभिधा विरचिता येनोदयाख्येन भू-
भर्त्रा सर्वधनैर्युता क्षितितले वैकुण्ठलोकाधिका ।
अग्रेऽस्यास्त्रिदशाधिपस्य नगरी पल्लीव संलक्ष्यते
यत्रस्थस्त्रिदिवौकसो जनगणो जित्वा विभात्यन्वहम् ॥ ५ ॥ [शार्दूलविक्रीडितम्]

rājñā puryudayābhidhā viracitā yenodayākhyena bhū-
bhartrā sarvadhanair yutā kṣititale vaikuṇṭhalokādhikā |
agre'syāstridaśādhipasya nagarī pallīva saṃlakṣyate
yatrasthas tridivaukaso janagaṇo jitvā vibhātyanvaham ||5||
[*śārdūlavikrīḍitam*]

By that king, Udaya by name, protector of the earth, a city, called Udaya (Udaipur), was created on the surface of the earth, filled with all kinds of riches, which surpassed even the world Vaikuṇṭha. In front of (i.e., in comparison to) this [city], even the city of the lord of the Gods (*tridaśa*) looks like a hamlet; by dwelling there (in Udaipur), the citizens are ever glowing having surpassed their counterparts in the heavens.

Continuing his praise for Udaya, Haridatta next turns from his personal attributes to some of his civic achievements. In particular, he notes Udaya's role as the founder and architect of the eponymously named city Udayapura. This is no doubt the current Udaipur, the historic capital of Mewar.

Here, the city of Udaipur is the subject of the figure of speech known as *atyukti*, or poetic exaggeration. In fact, there are three comparisons here which embody *atyukti*. These pertain to the resources of the city, its appearance, and the state of the citizens. Firstly, Haridatta describes Udaipur as filled with so many wonderful resources that it surpasses even Vaikuṇṭha.[15] Secondly, its level of comfort and embellishments make even a divine city look like a hamlet. Lastly, the citizens are radiant due to the fact that the luxury they enjoy has surpassed that of even the Gods. Such statements that place a terrestrial entity superior to a divine one are indeed poetic exaggerations.

MAHĀRĀṆA PRATĀPASIṂHA

The Exceptional Power of Pratāpasiṃha

प्रतापसिंहस्य अनितरसाधारणप्रतापः

तदात्मजः सङ्गररङ्गधीरः प्रतापसिंहो नृपतिर्बभूव ।
यत्पादपद्माश्रयिणो नरेन्द्राः मनोरथानाप्नुयुरप्यलभ्यान् ॥ ६ ॥ [उपजातिः]

प्रतापसिंहे नरराजराजे खड्गं दधाने करवारिजेन ।
श्रीपारिजातद्रुमपुष्पमालाः चक्रुः सुराधीशपुराङ्गनौघाः ॥ ७ ॥ [उपजातिः]

15 Vaikuṇṭha is a dwelling place of Lord Viṣṇu and considered to be the most beautiful, luxurious, and secure place to reside; even the goddess of wealth Lakṣmī herself has taken up residence there.

tadātmajaḥ saṅgararaṅgadhīraḥ pratāpasiṃho nṛpatir babhūva |
yatpādapadmāśrayiṇo narendrāḥ manorathān āpnuyur apy alabhyān ||6||

[*upajātiḥ*]

pratāpasiṃhe nararājarāje khaḍgaṃ dadhāne karavārijena |
śrīpārijātadrumapuṣpamālāḥ cakruḥ surādhīśapurāṅganaughāḥ ||7||

[*upajātiḥ*]

He had an offspring, Pratāpasiṃha, a king who was extremely skilful in the battlefield (*saṅgararaṅga*), by taking refuge unto whose lotus feet, subordinate kings, had their desires fulfilled which were otherwise unattainable.

When this emperor, Pratāpasiṃha, was carrying a sword in his lotus hand, the women in the courtyard of Indra came and offered garlands made of the Pārijāta tree.

Haridatta turns his attention next to Udaya's son, Pratāpasiṃha who reigned between 1572–1597. In the first half of verse 6, Haridatta uses the poetic phrase *saṅgararaṅgadhīra*—notably filled with alliteration—to succinctly portray Pratāpasiṃha as a skilled warrior. However, through the description in the second half of the verse he indirectly conveys that this power was not misused, but was tempered by benevolence and gentleness.

He further achieves this by a juxtaposition created between the powerful and warrior-like Pratāpasiṃha with a sword in hand encountering the women of Indra's courtyard, who counter his arrival with showers of flowers. This description in fact is suggestive (*dhvani*) of the fact that Pratāpasiṃha adheres to the *dharma* of relinquishing the sword and ceasing battle in the presence of women.

MAHĀRĀṆA AMARASIṂHA

The Glory of Amarasiṃha

अमरसिंहस्य प्रकर्षः

तदङ्गजो भूमिपतिर्बभूव देवेन्द्रतुल्योऽमरसिंहनामा ।
आसन् यदाख्याश्रवणाद्विपक्षाः नागा भयार्त्ता इव सिंहनादात् ॥ ८ ॥ [उपजातिः]

tadaṅgajo bhūmipatir babhūva devendratulyo 'marasiṃhanāmā |
āsan yadākhyāśravaṇād vipakṣāḥ nāgā bhayārttā iva siṃhanādāt ||8||

[*upajātiḥ*]

He had a son, Amarasiṃha by name, whose [glory] as a king was equal to that of Indra. As elephants (*nāgāḥ*) tremble out of fear upon hearing the roar of the lion, so too enemies would tremble merely by hearing his name.

Next, Haridatta moves on to Amarasiṃha, the son of Pratāpasiṃha. Fear and reverence are the dominant qualities emphasised by Haridatta in Amarasiṃha. These are achieved via two *upamā*s (simile), one in each half-verse. In addition, there is an intentional pun with the word *siṃha* here layered within this *upamā*. The pun arises from a double reading of the phrase *siṃhanādāt*. This compound can be simultaneously read as 'due to the sound [produced by uttering the name] *siṃha*' (that is, Jagatsiṃha, the name of the king) and as 'from the roar of a lion (*siṃha*)'. Likening the effect on people when a lion roars to uttering the name of someone emphasises their revered status.

MAHĀRĀṆA KARṆASIṂHA

Kindness and Generosity of Karṇasiṃha

कर्णसिंहस्य कारुण्यं दयालुत्वं च

तत्सूनुः किल कर्णसिंह इति यन्नाम्ना यथार्थाह्वयः
दानाधिक्यतया धनुर्धरतया तच्छत्रुतुल्योऽभवत् ।[16]
सत्यत्वेन युधिष्ठिराधिकरणं सौराज्यभावात् तथा
श्रीरामेण समः प्रतापनिकराधिक्यात् समो भानुना ॥ ९ ॥ [शार्दूलविक्रीडितम्]

tatsūnuḥ kila karṇasiṃha iti yannāmnā yathārthāhvayaḥ
dānādhikyatayā dhanurdharatayā tacchatrutulyo'bhavat |
satyatvena yudhiṣṭhirādhikaraṇaṃ saurājyabhāvāt tathā
śrīrāmeṇa samaḥ pratāpanikarādhikyāt samo bhānunā ||9||

[*śārdūlavikrīḍitam*]

Indeed he had a son, Karṇasiṃha by name. By virtue of possessing the quality of sharing in abundance, he became true to his name. [Also] by virtue of his skills in archery he was an equal of his (Karṇa's) enemy (i.e., Arjuna). Because of his truthfulness, he could take the place [i.e., qualified to bear the name] of Yudhiṣṭhira. Similarly, by virtue of providing good governance, he was an equal of Rāma. Because of the abundance of radiance, he was an equal of the Sun.

Continuing with the description of the lineage, this verse introduces the son of Amarasiṃha, Karṇasiṃha, who reigned from 1620–1628. In extolling Karṇasiṃha's virtues, Haridatta presents five revealing descriptions of qualities Karṇasiṃha possesses. These form poetic examples of *ullekha* (multiple allusions of one thing in different contexts). The first draws its literary force by his very name. Karṇasiṃha shares his name with the legendary Karṇa, a hero from the

16 We have emended the text from *tulyā* to *tulyo* in this quarter.

Mahābhārata known for his unparalleled virtue of sharing and generosity. The other four *ullekha*s pick out other different qualities by likening him to various heroes. These include Arjuna for his skills in archery, Yudhiṣṭhira for his honesty, Rāma for his good governance, and to Sūrya/the Sun for his abundant radiance.

MAHĀRĀṆA JAGATSIṂHA

Outstanding Qualities of Jagatsiṃha

जगत्सिंहस्य उत्कृष्टगुणाः

तदङ्गजन्मा धरणीं प्रशास्ति श्रीमान् जगत्सिंहनृपो महौजाः ।
धर्माधिकत्वेन दयालुभावात् यमेकलिङ्गं प्रवदन्ति सन्तः ॥ १० ॥ [उपजातिः]

tadaṅgajanmā dharaṇīṃ praśāsti śrīmān jagatsiṃhanṛpo mahaujāḥ |
dharmādhikatvena dayālubhāvāt yamekaliṅgaṃ pravadanti santaḥ ||10||

[*upajātiḥ*]

His son, Jagatsiṃha, as he was ruling the earth, was blessed with enormous wealth (*śrīmān*) and abundant courage, whom by virtue of his total commitment to righteousness and profuse compassion, the noble ones (*santaḥ*) declared [him] as as icon.

Finally, Haridatta reaches Jagatsiṃha, the son of Karṇasiṃha, the patron of the *Jagadbhūṣaṇa*. There are six verses dedicated to recounting Jagatsiṃha's many virtues, almost half the encomium. These verses are lavish in their praise. In this first verse, the figure of speech *hetu* (identifying a cause and its effects) is invoked to emphasise Jagatsiṃha's singular status.

Further Glorification of Jagatsiṃha's Virtues

जगत्सिंहस्य पुनर्गुणगानम्

श्रीमद्भूपजगन्नराधिपमहत्कीर्त्तिः प्रतापोज्वलः
क्रीडार्थं नगराद्बहिर्भवति चेत् यानं त्वदीयं विभो ।
श्रुत्वा शैलपुराधिपादिनरपाः स्वोकांसि सन्त्यज्य ते
किन्त्वस्मानभियास्यतीति चकिताः शीघ्रं प्रयान्ति क्वचित् ॥ ११ ॥

[**शार्दूलविक्रीडितम्**]

śrīmadbhūpajagannarādhipamahatkīrttiḥ pratāpojvalaḥ
krīḍārthaṃ nagarād bahir bhavati ced yānaṃ tvadīyaṃ vibho |
śrutvā śailapurādhipādinarapāḥ svokāṃsi santyajya te
kintvasmānabhiyāsyatīti cakitāḥ śīghraṃ prayānti kvacit ||11||

[*śārdūlavikrīḍitam*]

His majesty, king Jagat-[Siṃha], one of great fame [befitting] an emperor and [who] glows with valour, when he comes out of the city for the sake of sport, having heard [the noise] of your chariot, Oh Lord, the subordinate kings like the ruler of Śailapura, leaving their dwelling places, wondering 'Is he on his way towards us?', trembling, quickly move away somewhere else.

Elaborate praise for Jagatsiṃha continues in this verse, as Haridatta recounts his reputation amongst other kings in a playful way. The description that we find in this verse forms a beautiful instance of *bhrāntyalaṅkāra*, a poetic flourish that vividly describes an act of illusion.

The episode Haridatta narrates involves subordinate kings being under the spell of Jagatsiṃha's dominance. Indeed, Jagatsiṃha's reputation for power and dominance is such that the mere act of him moving out of the city in which he dwells is totally misconceived by subordinate kings as a potential attack against their smaller kingdoms. However, Haridatta completes the illusion by explaining that Jagatsiṃha is simply leaving for leisure: but this sportive act still induces fear in neighbouring rulers. Such a poetic flourish reinforces the superior status of Jagatsiṃha among other kings.

Imagery of Jagatsiṃha's Greatness

जगत्सिंहस्य औत्कृष्ट्यचिह्नम्

त्वत्प्रस्थाने तुरगखुरचलद्भूतधात्रीरजोभिः
व्याप्तं चेदं सकलमिह नभो श्रीजगत्सिंह यावत् ।
तावच्छ्रीमत्समदगजघटादानधाराभिराशु
क्लिन्नं पृथ्वीतलमखिलमलं राजते भूमिपालः ॥ १२ ॥ [चित्रलेखा]

tvatprasthāne turagakhuracaladbhūtadhātrīrajobhiḥ
vyāptaṃ cedaṃ sakalamiha nabho śrījagatsiṃha yāvat |
tāvacchrīmatsamadagajaghaṭādānadhārābhirāśu
klinnaṃ pṛthvītalamakhilam alaṃ rājate bhūmipālaḥ ||12|| [*citralekhā*]

As you depart, by the time the entire space here is filled with the dust of the earth generated from the movement of the horses' hooves, at that time by the flow of the rut that emanates from the frontal sinus (*ghaṭa*) of the elephants, [the dust] quickly becomes moistened and [settles] all over on the ground. Thus shines the king!

In order to emphasise Jagatsiṃha's majesty and importance, Haridatta turns to the size of his retinue. In doing so, he uses the figure of *atyukti*, or exaggeration. A dynamic image of horses' hooves churning up dust gives a stirring impression of the grandeur generated by the departure of Jagatsiṃha's cavalry and testifies to its large size. So many are the horses of his retinue that the earth their hooves whip up will fill the entire atmosphere with layers of dust and changes the hue of the surrounding area. However, the real hyperbole which adds to the drama is yet to come. Following the cavalry is a herd of elephants. So large and virulent is this herd, and, in turn, so copious the rut fluid emanating from them that the dust which was churned up by the horses will be dampened and the air will be cleared again. This exaggeration with its vivid imagery truly emphasises the size of Jagatsiṃha's army.

Comparing Jagatsiṃha With King Bhojarāja
जगत्सिंहस्य भोजराजेन तुलना

श्रीभोजदेवस्य जगन्नृपस्य वदन्ति साम्यत्वमहं न मन्ये ।
सकृत्कवित्वे स तु लक्षमेकं ददावयं लक्षसहस्रदायी ॥ १३ ॥ [उपजातिः]

śrībhojadevasya jagannṛpasya vadanti sāmyatvamahaṃ na manye |
sakṛtkavitve sa tu lakṣamekaṃ dadāvayaṃ lakṣasahasradāyī ||13||

[*upajātiḥ*]

They speak of the similarity of his majesty Bhojarāja with Jagatsiṃha. [However] I do not agree [with them]. By a single exhibition of the mastery of poetry, he (i.e., Bhojarāja) used to give one lakh (*lakṣa*) as a reward. [On the other hand] this [Jagatsiṃha] presents thousands of goals (*lakṣa*) [to be pursued which can bring countless rewards].

Haridatta continues his encomium to Jagatsiṃha by comparing him to another historical legendary king, Bhojarāja (*fl. ca.* 1010–1055), a polymath, celebrated for his extensive patronage of science, literature, and the arts. Such a comparison seems naturally fitting for a monarch such as Jagatsiṃha. However, Haridatta surprises his audience by turning this comparison on its head, arguing that it is more than mere similarity, rather Jagatsiṃha outshines even this historical celebrated monarch. In doing so, he employs the figure of *hetvapahnuti*. This is a poetic figure of speech related to *hetu*, but differs because of its use of a negation in the identification of a cause and an effect. In other words, *Hetvapahnuti* is said to occur when a statement is made involving a negation, following which the reason is supplied as to why it is being negated.

Given the glowing qualities of Bhojarāja, many poets would be tempted to make a comparison between Bhojarāja and Jagatsiṃha, in order to flatter the latter. However, this comparison is rejected by Haridatta in the clear statement invoking the first person singular: *ahaṃ na manye* 'I do not think [so]'. The reason he offers is that Jagatsiṃha rewards excellence with one thousand-fold the gift that Bhojarāja does. This negation accompanied with a reason thus completes the *hetvapahnuti*.

Layered in this figure of speech is another one, namely *śleṣa*, or an intentional pun. This is seen in the use of the word *lakṣa*. This can mean either a *lakh* (a sum of money) or equally, a target or goal that various people set to achieve in their lives. Thus, in addition to conveying that Jagatsiṃha is far more generous as a patron than Bhojarāja, Haridatta also appears to be insinuating that Jagatsiṃha's moral standard is such that rather than necessarily rewarding excellence with money, he believes it is more important to encourage people to pursue goals that will bring in long-lasting and substantial rewards.

Praising Jagatsiṃha's Generosity

जगत्सिंहस्य औदार्यप्रशंसा

चिन्तामणिः कामदुघा सुरद्रुः यच्छन्ति सङ्कल्पितमेव चित्ते ।
सन्मार्गणानां किल कल्पनायाः आधिक्यदत्वाद् विजिता त्वया ते ॥ १४ ॥

[इन्द्रवज्रा]

cintāmaṇiḥ kāmadughā suradruḥ yacchanti saṅkalpitam eva citte |
sanmārgaṇānāṃ kila kalpanāyāḥ ādhikyadatvād vijitāstvayā te ||14||

[*indravajrā*]

The wish-yielding gem, the heavenly cow, [and] the desire-granting tree bestow only whatever is wished for in the mind. [But] by granting much more than what is expected by the seekers of Truth (*sat*), Oh Lord, they have been [easily] won over by you.

Next, Jagatsiṃha's generosity is celebrated. To emphasise his magnanimity, Haridatta invokes the figure *vyatireka*, a form of comparison, but one in which the poet points out where the similarity ends. Here, Haridatta presents three standards of comparison in the verse: the wish-yielding gem, the heavenly cow, and the desire-granting tree. It is well known from the literature, that these three are capable of granting wishes. However, their capacity is limited to granting things which are specifically requested. Besides extolling Jagatsiṃha amongst these wish-granting entities, Haridatta stresses that Jagatsiṃha, because of his prescience and wisdom, invariably grants *more* than what is sought after by the noble seekers. Since he has superseded them in magnanimity, it is indeed apt that Haridatta describes Jagatsiṃha to have won over even these famous wish-granting objects.

Appreciation of Jagatsiṃha's Patronage and Asserting Authorship

जगत्सिंहस्य आश्रयश्लाघनं ग्रन्थकर्तृत्वप्रकथनं च

राजन् श्रीसबलाभिधाननृपतिर्मां प्रोक्तवांश्चिन्त्यतां
पृथ्वी येन भवेत् प्रभोः सकलगा कीर्त्तिः सदा स्थायिनी ।
तेनाहं हरिदत्तभट्टहरिदत्ताख्यस्त्वदीये[17] शके

17 The compound हरिदत्तभट्टहरिदत्ताख्यः is to be derived as follows: हरिदत्तश्चासौ भट्टहरिदत्ताख्यश्च.

पञ्चाङ्गग्रहाणादिलब्धिसहितां सिद्धिं खगानां ब्रुवे ॥ १५ ॥ [शार्दूलविक्रीडितम्]

rājan śrīsabalābhidhānanṛpatirmāṃ proktavāṃścintyatāṃ
pṛthvī yena bhavet prabhoḥ sakalagā kīrttiḥ sadā sthāyinī |
tenāhaṃ haridattabhaṭṭaharidattākhyastvadīye śake
pañcāṅgagrahāṇādilabdhisahitāṃ siddhiṃ khagānāṃ bruve ||15||

[*śārdūlavikrīḍitam*]

Oh King! The lord of the people, his excellency Sabala by name, told me to think of a means by which your majesty's fame will be lofty (*pṛthvī*), widespread, and remain forever. Therefore, I, Haridatta-bhaṭṭa by name, [and who was] brought into existence [by the grace] of Hari (Haridatta), narrate the [procedure for the] determination [of the longitudes] of the planets along with the calculation of the *pañcāṅga*, eclipses, and so on, [aligned with] your *śaka* era (*tvadīye śake*).

Haridatta finally claims his authorship and reveals that he wrote the work primarily to make the name of Jagatsiṃha both famous and enduring. He also indicates the instances that led him to that activity. As both cause and effect have been explicitly mentioned in the verse, the figure of speech here can be identified as *hetu*. The ultimate cause is to make the name of Jagatsiṃha everlasting. The effect is the production of a comprehensive astronomical work, which is expressly tied to the reign of Jagatsiṃha by means of its epoch, which is noted to be set at 10 years after his accession. For this, Haridatta uses the phrase *tvadīye śake* ("your śaka era").

This verse also contains a pertinent historical reference which gives us insight into the circumstances through which this work was produced. Haridatta expressly refers to a King called Sabala. It seems that he is referring Sabala Siṃha who had royal favour for his success in the battle of Peshawar, and whom as a result the emperor Shāh Jahān granted right of governance of the city of Jaisalmer. Haridatta relates that it was Sabala who suggested to him to find some way to ensure that Jagatsiṃha was remembered in perpetuity. It is perhaps no coincidence that the very nature of these tables, being cyclic, have no time limit, and are able to be used in perpetuity.

The Reign of Jagatsiṃha
जगत्सिंहस्य प्रशासनम्

शालिवाहनमहीपतिशाके
पूर्णबाणविषयेन्दुसमाने ।
श्रीजगन्नरपतिर्निजशाकं
भूरिदानजनितं कुरुते स्म ॥ १६ ॥ [स्वागता]

śālivāhanamahīpatiśāke
pūrṇabāṇaviṣayendusamāne |
śrījagannarapatir nijaśākaṃ
bhūridānajanitaṃ kurute sma || 16 || [*svāgatā*]

In the *Śaka* year 1550 (*pūrṇabāṇaviṣayendu*) his excellency Jagatsiṃha, the lord of the people, occasioned with abundant sharing [his] own year [of accession].

Haridatta provides the year of the commencement of the reign of Jagatsiṃha: his reign began on *Śaka* year 1550 (*pūrṇabāṇaviṣayendu*) (i.e., 1628 CE). Haridatta also states that Jagatsiṃha celebrated this occasion by abundantly distributing his wealth to the citizens of his kingdom.

The Epoch of the Text

ग्रन्थशाकः

श्रीमद्विक्रमसंज्ञकस्य धरणीभर्तुः शराग्नीन्दुभिः
हीने स्यात् किल शालिवाहनधराधीशस्य शाकः स्फुटम् ।
तस्मिन् पूर्णशरेन्द्रियेन्दुरहिते श्रीमज्जगत्सिंहभू-
भर्तुः शाकवरः खचन्द्ररहितोऽब्दानाङ्गणो ग्रन्थजः ॥ १७ ॥

[**शार्दूलविक्रीडितम्**]

śrīmadvikramasaṃjñakasya dharaṇībhartuḥ śarāgnīndubhiḥ
hīne syāt kila śālivāhanadharādhīśasya śākaḥ sphuṭam |
tasmin pūrṇaśarendriyendurahite śrīmajjagatsiṃhabhū-
bhartuḥ śākavaraḥ khacandrarahito'ṣṭānāṅgaṇo granthajaḥ || 17 ||

[*śārdūlavikrīḍitam*]

When the [year] corresponding to the protector of the earth, his excellency Vikrama, is diminished by 135 (*śarāgnīndu*), indeed, the *Śaka* year based on the lord of the world Śālivāhana is correctly obtained. When that [*Śaka* year] is diminished by 1550 (*pūrṇaśarendriyendu*), [there results] the regnal *Śaka* years (*śākavara*) of Jagatsiṃha, the ruler of the world (i.e., the number of years since his accession to the throne). [That further] diminished by 10 (*khacandra*) [gives] the count of years [elapsed since] the composition of the text.

The beginnings of *Vikrama-saṃvat* era and the *Śaka* era are two commonly used epochs in the Indian calendar system. The former begins in 57 BCE, while the latter begins in 78 CE, thus the interval of time between the two is 135 years. With this established, Haridatta states the procedure for determining the number of years elapsed since the beginning of the reign of his patron Jagatsiṃha: taking the difference between the current *Śaka* year and *Śaka* 1550 (equivalent to

1628 CE). Then, he indirectly establishes the epoch year for the *Jagadbhūṣaṇa* to be 10 years after this, namely *Śaka* 1560 (1638 CE), at the end of this verse.

PROCEDURE FOR OBTAINING THE MEAN AND TRUE MOON AND SUN AND THEIR RELATED PARAMETERS

Obtaining the Lord of the Year, Epact, the Moon and its Anomaly
अब्दपशुद्धिचन्द्रकेन्द्राणाम् आनयनम्

ग्रन्थाब्दवृन्दं निजचक्रमित्या
भजेत्ततः शेषमिताङ्ककोष्ठे ।
वर्षादिजान्यब्दपशुद्धिचन्द्र-
केन्द्राणि सन्त्यब्दपकालजानि ॥ १८ ॥ [उपजातिः]

granthābdavṛndaṃ nijacakramityā
bhajet tataḥ śeṣamitāṅkakoṣṭhe |
varṣādijānyabdapaśuddhicandra-
kendrāṇi santyabdapakālajāni || 18 || [*upajātiḥ*]

One should divide the count of years [elapsed] since [the year of] the text-[composition] by the measure of their own cycle (*nijacakra*). Then, the lord of the year (*abdapa*), the epact (*śuddhi*), the longitude of the moon (*candra*) and [its] anomaly (*kendra*) are found in the table number commensurate with the remainder, evaluated at the time of the lord of the year (i.e., the beginning of the year).

With the number of years elapsed since the epoch in hand, Haridatta explains how to convert this quantity into an appropriate tabular argument to determine the lord of the year, epact, the longitude of the moon, and lunar anomaly at the beginning of a desired year from the accompanying tables. One is instructed to divide the number of years that have elapsed since the epoch by the appropriate cycle number (*cakra*) associated with each of these four phenomena. (These cycle number dividers are given in the next verse.) The remainder from this division provides the tabular argument for retrieving the appropriate value from the tables.

Lord of the Year (abdapa)

By convention, the so-called 'lord of the year' (Sanskrit: *abda-pa*) associates one of the seven planets to the weekday on which the sun enters the zodiacal sign of Aries marking the beginning of the solar year (*Meṣasaṅkrānti*). Numerically it is generated by continuously adding the difference between the length of a sidereal year and fifty-two 7-day weeks.

To determine the accumulated lord of the year for any year since the epoch, Haridatta provides a table (see Table 7) with 89 argument values numbered

Number	Lord of the year	Weekday
0	Venus	Friday
1	Saturn	Saturday
2	Sun	Sunday
3	Moon	Monday
4	Mars	Tuesday
5	Mercury	Wednesday
6	Jupiter	Thursday

Table 6: Lord of the year.

0 to 88.[18] The numerical entries in the table correspond to the integral number of days (modulo 7) and their fractional parts precise to the third fractional sexagesimal place and represent the instant when the Sun enters the beginning of Aries from year to year.

The table entries have been generated by an epoch value (the first entry of the table, namely $6;56,14,30$) and a constant difference. This epoch value can be reconstructed using Haridatta's sidereal year length[19] and the number of years elapsed since the beginning of the Kaliyuga (i.e., 3102 BCE) to the epoch of the work (1638 CE), namely 4739 years:

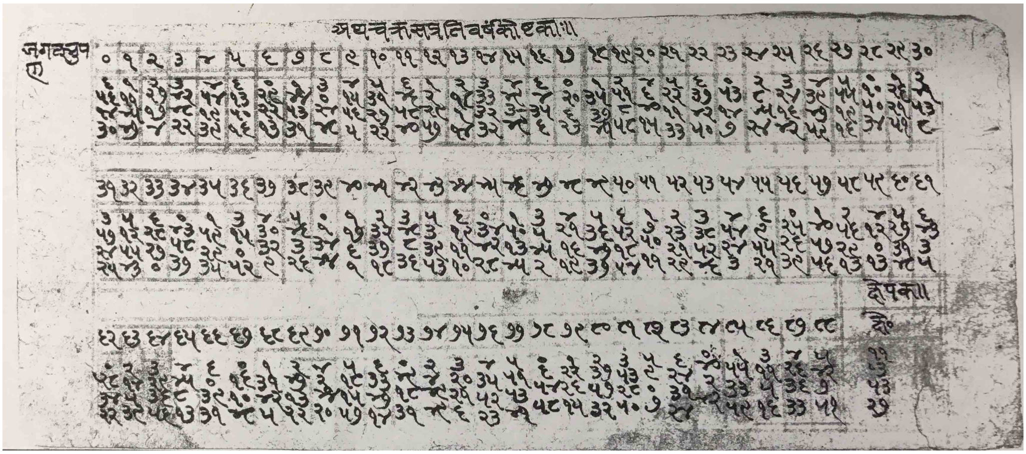
$$4739 \times 365;15,31,17,17 = 1730960;56,14,05,43 \quad (1)$$
$$= 6;56,14,05,43 \pmod 7. \quad (2)$$

Subsequent tabular values have been generated via a constant difference (1;15,31,17,17), namely the amount by which the sidereal year (Y_{sid}) exceeds fifty-two 7-day weeks or twenty-six 14-day *avadhi*:

$$abdapa = Y_{sid} - 26 \times 14 \quad (3)$$
$$= 365;15,31,17,17 - 364 \quad (4)$$
$$= 1;15,31,17,17 \text{ days.} \quad (5)$$

The actual lord of the year weekday can be determined from the first row of the numerical entries. The designations 0 to 6 are numerical representations corresponding to the seven individual planets conventionally associated with each particular weekday (Table 6).

18 The eighty-nine entries reflect the cycle



Y	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
abdapa	6	1	2	3	4	6	0	1	3	4	5	6	1	2	3	4	6	0	1	2	4	5	6	0	2	3	4	5	0	1	2
	56	11	27	42	54	13	29	44	0	15	31	46	2	18	33	49	4	20	35	51	6	22	37	53	8	24	39	55	10	26	41
	14	45	17	48	19	50	22	53	24	56	27	58	29	1	32	3	35	6	37	8	40	11	42	14	5	16	47	19	50	21	53
	30	47	4	22	39	16	13	31	48	5	22	40	57	14	32	49	6	23	41	58	15	33	50	7	24	42	59	16	34	51	8
Y	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
abdapa	3	5	6	0	1	3	4	5	0	1	2	3	5	6	0	1	3	4	5	6	1	2	3	4	6	0	1	2	4	5	6
	57	12	28	43	59	15	30	46	1	17	32	48	3	19	34	50	5	21	36	52	7	23	38	54	9	25	40	56	12	27	43
	24	55	27	58	29	0	32	3	34	6	37	8	39	11	42	13	45	16	47	18	50	21	52	24	55	26	57	29	0	31	3
	25	43	0	37	35	52	9	26	44	1	18	36	53	10	28	45	2	19	37	54	11	29	46	3	21	39	56	13	13	48	5
Y	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88			*kṣe*	
abdapa	0	2	3	4	6	0	1	2	4	5	6	0	2	3	4	5	0	1	2	3	5	6	0	1	3	4	5			11	
	28	14	29	45	0	16	31	47	2	18	33	49	4	20	35	51	6	22	37	53	9	24	40	55	11	26	42			3	
	34	5	36	8	39	10	42	13	44	15	47	18	49	21	52	53	54	26	57	28	0	31	2	33	5	36	7			53	
	22	39	56	13	31	48	5	22	20	57	14	31	49	6	23	41	58	15	32	50	7	24	42	59	16	33	51			27	

Table 7: Values of the lord of the year (*abdapa*) in weekdays and sexagesimal fractional parts to three places for argument 0 to 88 years (MS **P**, f. 96r). In the bottom right-hand corner a tabular entry labeled *kṣe*, short for *kṣepaka* ('additive quantity'), presumably indicates the constant difference between successive entries. This is not the constant difference for this table but rather for the following table of epact values.

number that Haridatta has selected for the lord of the year. For details, see verse 19.

19 Haridatta explicitly claims to be following the *Brāhmapakṣa* (see *Jagadbhūṣaṇa* 3.1) and his underlying sidereal year length can be derived as follows: The year length used in the *Brāhmasphuṭasiddhānta* by Brahmagupta (Pingree 1970: 95) is:

$$Y_{sid} = 365; 15, 30, 22, 30 \text{ days.}$$

Around the beginning of the second millennium BCE, this was later refined by so-called one off *bīja* corrections. A known correction was due to Bhojarāja and his proposed *bīja*

Epact (*Śuddhi e*)

The epact (*śuddhi*) is the excess of the length of a sidereal year over a mean lunar year. It is specified in lunar days (*tithi*s). Haridatta provides a table (see Table 8) pertaining to the epact with 122 argument values numbered 0 to 121. The constant differences in the table entries show that Haridatta takes the annual epact to be 11;3,53,22,40.[20]

The value of the epact chosen by Haridatta can be tentatively reconstructed using *Brāhmapakṣa* parameters.[21]. Here the rate of increase in elongation per civil day between the mean moon and the mean sun is:

$$13^\circ; 10, 34, 52, 46 - 0^\circ; 59, 8, 10, 22 = 12^\circ; 11, 26, 42, 24. \tag{6}$$

Using this mean elongation, the length of the mean synodic (lunar) month is found to be:

$$\frac{360}{12^\circ; 11, 26, 42, 24} = 29; 31, 50, 5, 45 \text{ civil days.}$$

Thus, the duration of the mean lunar year is:

$$12 \times 29; 31, 50, 5, 45 = 354; 22, 1, 9, 8 \text{ civil days.}$$

Now, the value of the epact in civil days is obtained by finding the difference between this and the length of the sidereal year:

$$365; 15, 31, 17, 17 - 354; 22, 1, 9, 8 = 10; 53, 30, 8, 9 \text{ civil days.}$$

The above value can be turned into the units of *tithi*s by multiplying it the ratio of *tithi*s to civil days, namely multiplying by 30 and dividing by 29;31,50,5,45:[22]

$$10; 53, 30, 8, 9 \times \frac{30}{29; 31, 50, 5, 45} = 11; 3, 53, 25 \text{ } \textit{tithi}\text{s.}$$

adjustment (Pingree 1996: 163):

$$Y_{sid} = 365; 15, 30, 22, 30 + 0; 0, 0, 54, 47, 19$$
$$= 365; 15, 31, 17, 17 \text{ days.}$$

This year length is attested in many second millennium sources (see, for instance, Kolachana, Montelle, et al. (2018: 312)), such as the *Mahādevī* of Mahādeva and the *Candrārkī* of Dinakara.

20 This value is identical to that given in the *Candrārkī*. See (Pingree 1968: 56) and (Kolachana, Montelle, et al. 2018: 318).

21 For a list of these see, for instance, Montelle and Plofker (2018: Appendix B, 277)

22 This ratio is notably more precise than the conversion ratio of 60 to 59 Haridatta gives later in the work (verse 21–22). Using this less precise ratio in the reconstruction here doesn't produce the required precision for the *śuddhi* value.

which is very close to the value given by Haridatta, namely 11;3,53,22,40.[23] Intermediate rounding or using truncated parameters in the computation may account for this very small discrepancy in the third sexagesimal place.

The epact at the epoch, namely the first value in the table (26;11,41,50), can be tentatively derived as follows:

$$4739 \times 11;03,53,22,40 = 14,33,56;12,57,17,20 \text{ or}$$
$$= 26;12,57,17 \text{ (mod 30)}.$$

Here again, it may be noted that this is very close to Haridatta's value, with a very small deviation of 0;1,15,27 *tithi*.

This table is useful in obtaining the number of civil days that have elapsed since the beginning of the year from the count of the elapsed *tithi*s. This value is required for procedures detailed later in the work (see section 3).[24]

Longitude of the Moon (*Candra* λ_M)

As an aid to the computation of the true longitude of the moon, Haridatta provides a table that lists the mean longitudes of the moon at the beginning of every year, with 122 argument values numbered 0 to 121 (see Table 9). The epoch value is $10^r 14^\circ;20,22 = 314^\circ;20,22$ and the annual increment (mod 360) is $132^\circ;46,40,32$ degrees. The magnitude of this increment can be derived from the mean daily motion of the moon and the length of the year:

$$13;10,34,52,31,44 \times 365;15,31,17,17 = 4812;46,40,32$$
$$= 132;46,40,32 \text{ degrees (mod 360)}.$$

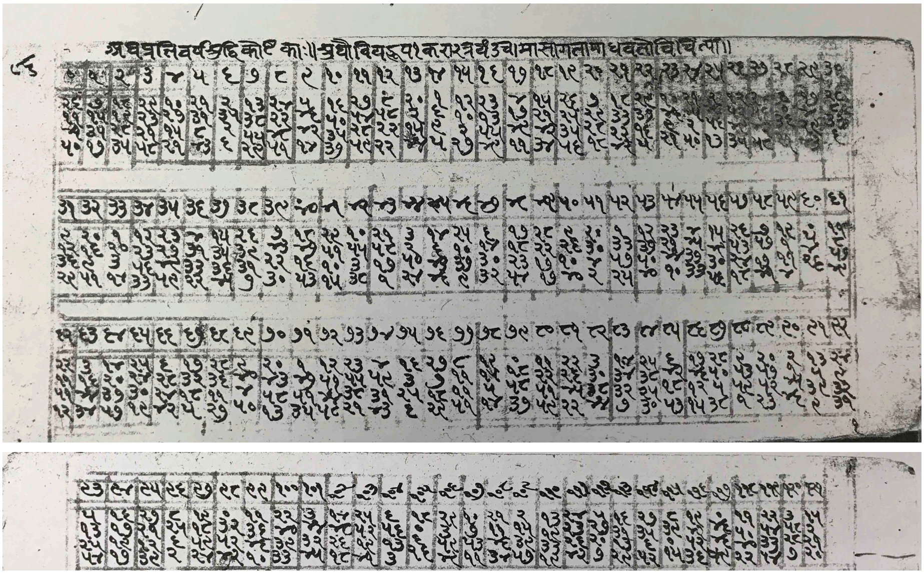
Likewise, the epoch value of the mean longitude of the moon can be computed to be:

$$4739 \times 132;46,40,32 = 2,54,47,14;35,27,28 \text{ or}$$
$$= 314;35,27,28 \text{ degrees (mod 360)}.$$

This assumes that the sun and the moon were in conjunction at the beginning of the Kaliyuga. While this reconstruction is close to the tabulated epoch value, there is still a small discrepancy of $0^\circ;15,05,28$.

23 In fact this reconstructed value (11;3,53,25) is very close to the value (11;3,53,22,40) included in the table right at the very end under the label *kṣe*, short for *kṣepaka* ('additive'). We are not able to explain why this noted *kṣepaka* value is slightly different from the actual constant differences in the tabulated values.

24 The header text of *śuddhi* table reads: *śuddhau viyadrūpakarāstrayaṃ ca māsā gatā mādhavato vicintyāḥ*. This is very similar to related text in the table text *Candrārkī* (see Kolachana, Montelle, et al. (2018: 331, verse 13)).

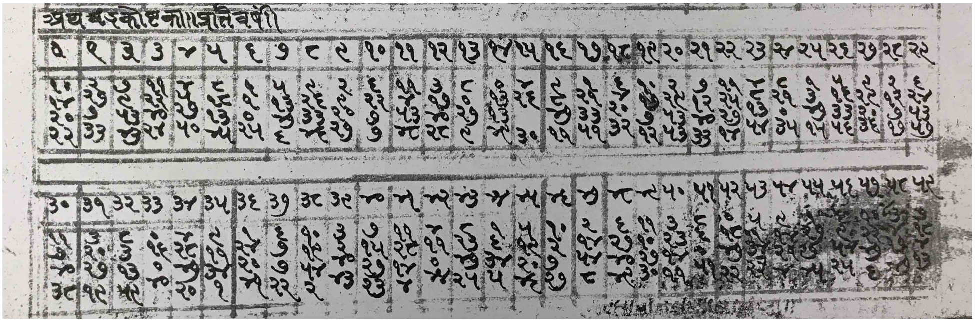


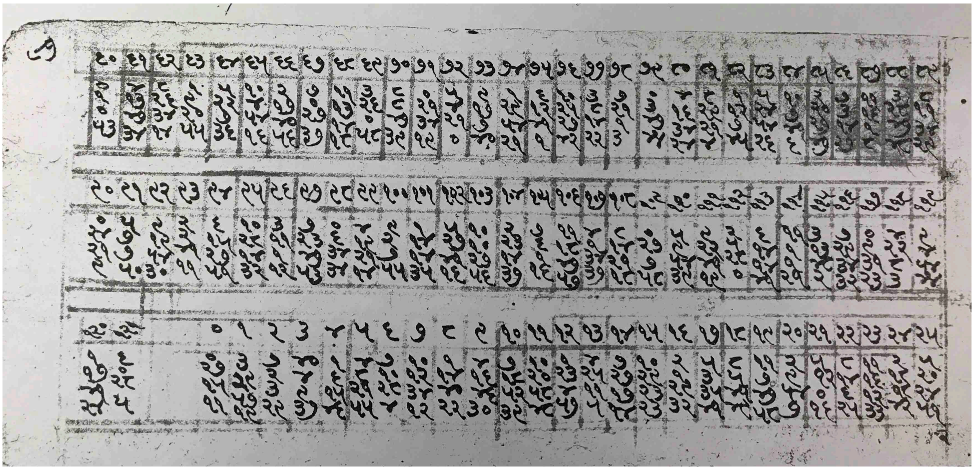
Y	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
śuddhi	26	7	18	29	10	21	2	13	24	5	16	27	8	20	1	12	23	4	15	26	7	18	29	10	21	2	12	24	6	17	28
	11	15	19	23	27	31	35	38	22	46	50	54	58	2	6	10	13	17	21	25	29	33	37	46	45	48	52	56	0	4	8
	41	35	28	21	15	8	2	55	48	42	35	28	22	15	9	2	55	49	42	35	28	22	16	9	2	56	49	42	36	29	33
	50	17	35	58	21	43	6	29	51	14	37	59	22	44	5	27	49	11	34	56	18	42	5	21	50	13	35	58	21	43	6
Y	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
śuddhi	9	20	1	12	23	4	15	26	7	18	29	10	21	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7	19	0	11
	12	16	20	23	27	31	35	39	43	47	51	55	58	2	6	10	14	18	22	26	30	33	37	21	45	49	53	57	1	5	8
	36	9	3	56	49	33	36	31	22	16	10	3	17	50	43	37	30	23	17	10	4	57	50	44	37	30	24	17	11	4	57
	29	51	14	33	59	22	45	7	30	53	15	38	1	24	46	9	32	54	17	40	2	25	40	10	33	56	18	41	4	26	49
Y	12	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
śuddhi	22	3	14	25	6	17	28	9	20	1	12	23	4	16	27	8	19	0	11	22	3	14	25	6	17	28	9	20	2	13	24
	11	16	20	24	28	32	36	40	43	47	51	55	59	3	7	11	15	18	22	26	30	34	38	42	46	50	53	57	1	5	9
	51	44	37	30	24	18	11	4	58	51	44	38	31	25	18	11	5	58	51	45	38	32	25	18	12	5	59	52	45	39	32
	12	34	57	19	42	5	27	50	13	35	58	21	43	6	29	51	14	37	59	22	44	7	30	53	15	38	1	23	46	9	31
Y	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121		
śuddhi	5	16	27	8	19	0	11	22	3	14	25	6	18	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3	15		
	13	17	21	25	18	32	36	40	44	48	52	56	0	3	7	11	15	19	23	27	31	35	39	42	46	50	54	58	2		
	25	19	12	6	59	52	46	39	32	26	19	13	6	59	53	46	39	33	26	20	13	6	0	52	46	40	33	28	21		
	54	17	39	2	24	42	10	33	45	18	41	3	26	49	11	34	57	19	42	7	29	52	16	36	59	22	54	7	20		

Table 8: Values of the epact (*śuddhi*, *e*) in *tithis* and sexagesimal fractional parts to three places for argument 0 to 121 years (MS **P**, ff. 96v–97r).

Lunar Anomaly (*kendra* λ_K)

The lunar anomaly (*kendra*) is the difference between the longitudes of the moon and its apogee. Haridatta provides a table (see Table 10) with 43 argument values numbered 0 to 42. The numerical values in the table have been generated





Y	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Longitude	10	2	7	11	4	8	1	5	9	2	6	11	3	8	0	4	9	1	6	10	2	7	11	4	8	1	5	9	2	6	11
	14	27	9	22	5	18	1	13	26	9	22	4	17	0	13	26	8	21	4	17	29	12	25	8	21	3	16	29	12	24	7
	20	7	53	40	27	13	0	47	33	20	7	53	40	27	13		47	33	20	7	53	40	27	13	0	47	33	20	7	53	40
	22	33	43	24	50	45	25	6	46	27	7	48	28	9	49	30	11	51	32	12	53	33	14	54	35	15	56	36	17	57	38
Y	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Longitude	3	8	0	4	9	1	6	10	3	7	11	4	8	1	5	10	2	6	11	3	8	0	5	9	1	6	10	3	7	0	4
	20	3	16	28	11	24	7	19	2	15	28	11	23	6	19	2	14	27	10	23	6	18	1	14	27	9	22	4	18	1	13
	27	13	0	47	34	20	7	54	40	27	14	0	47	34	20	7	54	40	27	14	0	47	34	21	7	54	47	17	4	0	47
	19	59	40	20	1	41	22	2	43	23	4	44	25	5	46	27	8	49	30	11	51	22	22	4	45	25	6	47	13	53	34
Y	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Longitude	8	1	5	10	2	7	11	3	8	0	5	9	1	6	10	3	7	0	4	8	1	5	10	2	7	11	3	8	0	5	9
	26	9	22	4	17	0	13	26	8	21	4	17	29	12	25	8	21	3	16	29	12	24	7	20	3	16	28	11	24	7	19
	34	20	7	54	40	27	14	0	47	34	21	7	54	41	27	14	1	47	34	21	7	54	41	27	14	1	47	34	21	7	54
	14	55	36	16	56	37	18	58	39	19	0	40	21	1	42	22	3	44	24	4	45	26	6	47	27	8	48	29	9	50	30
Y	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121		
Longitude	2	6	10	3	7	0	4	9	1	5	10	2	7	11	4	8	0	5	9	2	6	11	3	7	0	4	9	1	6		
	2	15	28	11	23	6	19	2	14	27	10	23	6	18	1	14	27	9	22	5	14	1	13	29	9	22	4	17	0		
	41	27	14	1	47	34	21	7	14	41	27	14	1	47	34	21	7	54	41	28	14	1	48	34	31	8	54	41	28		
	11	51	32	12	53	34	14	55	35	16	56	37	16	57	37	18	58	39	19	0	41	21	2	32	23	3	44	24	5		

Table 9: Longitudes of the moon in zodiacal signs, degrees, and sexagesimal fractional parts to two places for argument 0 to 121 years (MS **P**, f. 97r/v).

by an epoch value of $0^\circ;27,51,11$ and a constant difference of $3^r2^\circ;6,8 = 92^\circ;6,8$ which corresponds to the mean annual longitudinal displacement (modulo 360). Using *Brāhmapakṣa* parameters for the mean daily motion of the moon and the apogee, the mean daily motion of the lunar anomaly is:[25]

$$13;10,34,52,46,30 - 0;6,40,53,56 = 13;3,53,58,50,30,$$

and its mean annual longitudinal displacement is, therefore:

$$\begin{aligned} 13;3,53,59 \times 365;15,31,17,17 &= 4772;6,11,11,26 \\ &= 92;6,11,11 \pmod{360} \end{aligned}$$

which is very close to Haridatta's value.

The epoch value should thus be

$$\begin{aligned} 4739 \times 92;6,8 &= 436472;25,52 \text{ or} \\ &= 152;25,52 \text{ degrees } \pmod{360}. \end{aligned}$$

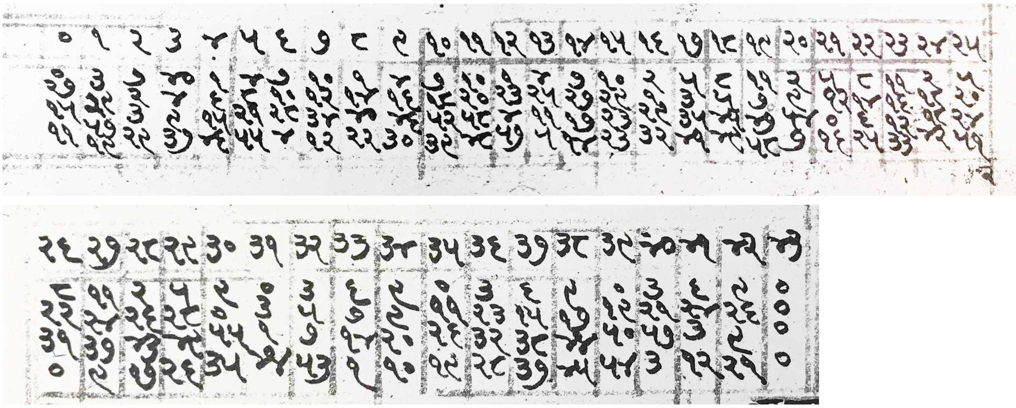
This value is quite different from the tabulated amount. This discrepancy may be explained by the fact that the lunar apogee was generally not taken to be zero at the beginning of the Kaliyuga. For instance, in the twelfth-century *Siddhānta-śiromaṇi* of Bhāskara II, the epoch position of the apogee at the beginning of the Kaliyuga (*dhruva*) was set at $4^r5^\circ;29,46$ (Arkasomayaji 1980: 43). Likewise, in the sixteenth-century *Tantrasaṅgraha* of Nīlakaṇṭha, the correction was set at $3^r29^\circ;17$ (Ramasubramanian and Sriram 2011: 45). It may be a similar correction was made in this case too.

Cyclic Periods of the Lord of the Year and So On
अब्दपादीनां चक्राणि

गोकुञ्जरा वर्षपतेश्च चक्रं
शुद्धेर्निशेशस्य भुजद्विचन्द्राः ।
कृशानुवेदाः किल केन्द्रकस्य
पुनर्भ्रमश्चक्रमितैर्गताब्दैः ॥ १९ ॥ [उपजातिः]

gokuñjarā varṣapateś ca cakraṃ
śuddher niśeśasya bhujadvicandrāḥ |
kṛśānuvedāḥ kila kendrakasya
punar bhramaś cakramitair gatābdaiḥ || 19 || [*upajātiḥ*]

25 The mean daily motion of the lunar anomaly is stated explicitly in verse 28 as $13^\circ;3,54$. This less precise value does not produce the required results in the reconstruction here.



Y	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Longitude	0	3	7	40	1	4	7	10	1	4	7	10	1	4	7	10	2	5	8	11	2	5	8	11	2	5
	27	29	2	4	6	8	10	12	14	16	18	20	23	25	27	29	1	3	5	7	9	12	14	16	18	20
	15	57	3	9	15	21	28	34	40	46	52	58	4	11	17	23	29	35	41	47	54	0	6	12	18	24
	11	19	29	37	46	55	4	12	22	30	39	48	57	5	14	23	32	41	49	58	7	16	25	33	42	51

Y	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Longitude	8	11	2	5	9	0	3	6	9	0	3	6	9	0	3	6	9	0
	22	24	26	28	0	3	5	7	9	11	13	15	17	19	21	24	26	0
	31	37	43	49	55	1	7	14	20	26	32	38	44	50	57	3	9	0
	0	9	17	26	35	44	53	1	10	19	28	37	45	54	3	12	21	0

Table 10: Values of the lunar anomaly (*kendra*) in zodiacal signs, degrees, and sexagesimal fractional parts to two places for argument 0 to 42 years (MS **P**, ff. 97v–98r).

> The cyclic-period of the lord of the year is 89 (*gokuñjara*), of the epact and of the moon 122 (*bhujadvicandra*), and that of the lunar anomaly 43 (*kṛśānuveda*). The the same pattern [repeats after the number of] elapsed years corresponding to the cycle.

This verse provides the cyclic numbers (*cakras*) measured in years for the lord of the year, the epact, the moon, and its anomaly. These numbers have been selected so as to ensure the astronomical phenomenon in question returns to the same circumstances at which it started (or very close to it). Table 11 lists the cycle numbers of the parameters measured in years, their annual increments and the residuals obtained after multiplying the cycles and their yearly increments.

Parameter	Cyclic period	Annual increment	Residual
Lord of the year (days)	89	1; 15, 31, 17, 17	+ 0; 01, 24, 38 mod 7
Epact (*tithi*s)	122	11; 3, 53, 22, 40	− 0; 05, 27, 54 mod 30
Lunar longitude (degrees)	122	132; 46, 40, 32	− 01; 05, 34, 56 mod 360
Lunar anomaly (degrees)	43	92; 06, 08, 48	+ 0; 24, 18, 24 mod 360

Table 11: Cyclic periods in years as listed in verse 19, their annual increments and their computed residuals after one complete cycle.

Parameter	Cyclic-period correction factor
Lord of the year	+1/42 = +0; 01, 25, 42 day
Epact	−1/11 = −0; 05, 27, 16 *tithi*
Lunar longitude	−1/55 = −01°; 05, 27, 16
Lunar anomaly	+1/148 = +0°; 24, 19, 27

Table 12: The cyclic-period correction factors listed in verse 20.

Corrections for Cycles of the Lord of the Year and So On

अब्दपादीनां चक्रसंस्काराः

गतानि चक्राणि भजेत् द्विवेदैः
अष्टेन्द्रकैरब्दपकेन्द्रयोश्च ।
धनं क्रमेणाथ शिवैश्च शुद्धौ
इन्दावृणं बाणशरैर्विधेयम् ॥ २० ॥ [उपजातिः]

gatāni cakrāṇi bhajet dvivedaiḥ
aṣṭendrakair abdapakendrayoś ca |
dhanaṃ krameṇātha śivaiś ca śuddhau
indāv ṛṇaṃ bāṇaśarair vidheyam ‖ 20 ‖ [*upajātiḥ*]

One should divide the completed cycles of the lord of the year and the lunar anomaly by 42 (*dviveda*) and 148 (*aṣṭendraka*) respectively [and] apply [the quotient] positively. Similarly, [one should divide the completed cycles] of the epact and the moon and by 11 (*śiva*) and 55 (*bāṇaśara*) [respectively], and apply [them] negatively.

As noted in Table 11, when the annual increments associated with each of these parameters are multiplied by their cyclic period they leave a small residual. To account for this residual, which will accumulate over multiple cycles, Haridatta proposes fractional corrections in each case. Table 12 lists these corrections.

Calculating the Elapsed Civil Days from tithis
तिथिभ्यः सावनदिनानयनम्

मधोः सितादेर्गतमाससंख्या
त्रिंशद्गुणा षष्टिविभागहीना ।
शुद्ध्या विहीना गतघस्रयुक्ता
गणो भवेदब्दपवारमुख्यः ॥ २१ ॥ [उपजातिः]

अभीष्टस्य गणस्याधः निवेश्याश्चेष्टनाडिकाः ।
वर्षेशनाडिकास्तस्मात् शोधनीयाः स्फुटो गणः ॥ २२ ॥ [अनुष्टुप्]

madhoḥ sitāder gatamāsasaṃkhyā
triṃśadguṇā ṣaṣṭivibhāgahīnā |
śuddhyā vihīnā gataghasrayuktā
gaṇo bhaved abdapavāramukhyaḥ ‖ 21 ‖ [*upajātiḥ*]

abhīṣṭasya gaṇasyādhaḥ niveśyāś ceṣṭanāḍikāḥ |
varṣeśanāḍikās tasmāt śodhanīyāḥ sphuṭo gaṇaḥ ‖ 22 ‖ [*anuṣṭup*]

The number of months elapsed since the beginning of the bright half of Madhu, multiplied by 30, decreased by the epact, [and] increased by the elapsed [lunar] days (*ghasra*), decreased by a 60th part [of the resulting *tithi*s], produces the count [of civil days], commencing with the weekday of the lord of the year.

The desired *nāḍikā*s [of the chosen day] are to be placed underneath the desired count [of civil days]. The *nāḍikā*s of the lord of the year are to be subtracted from that [which gives] the accurate count [of civil days].

These verses describe a simple yet reasonably accurate method for determining the number of elapsed civil (solar) days from the start of the year (i.e., *Meṣasaṅkrānti*) to a given date and time by converting elapsed *tithi*s into civil days.[26] The lunar year begins with the first *tithi* (*pratipadā*) of the bright half (*śukla*) of the month Madhu.[27] To calculate the elapsed civil days, first the elapsed lunar months m are multiplied by 30 and the elapsed *tithi*s of the current month τ_0 are added to it in order to determine the total number of elapsed *tithi*s (τ) since the beginning of the current lunar year.

$$\tau = m \times 30 + \tau_0. \tag{7}$$

26 A similar verse can be found in Dinakara's *Candrārkī* (verse 11):
मधोर्गताः स्युः खगुणैर्विनिघ्ना
युक्तास्तिथीभिर्गतसंख्यकाभिः ।
शुद्ध्योनिताः षष्टिविभागहीनाः
गणो भवेद्वर्षपतेः सकाशात् ॥
(Kolachana, Montelle, et al. 2018: 329–330).

27 Madhu, Mādhava, etc., are the names of the lunar months found in the Vedic literature, as alternatives to the more standard Caitra, Vaiśākha, etc.

Next, the epact e corresponding to that year is to be subtracted from τ to obtain τ'.

$$\tau' = \tau - e. \tag{8}$$

This produces the number of elapsed *tithis* from *Meṣasaṅkrānti*. Finally, the resulting collection of *tithi*s is diminished by a sixtieth part in order to convert *tithi*s to civil days d as per the following formula:

$$d = \left(1 - \frac{1}{60}\right)\tau'. \tag{9}$$

This conversion is based on the assumption that 59 *tithi*s are equivalent to 60 civil days.

Lastly, one is to take into account fractional parts of the day. To do this, one subtracts the fractional part of the lord of the year parameter (n_L) from the fractional part that has elapsed on the current day (n_T), since the exact instant of *Meṣasaṅkrānti* depends on the fractional value of the lord of the year parameter. The resulting count of elapsed civil days is then measured from mean sunrise rather than the instant of *Meṣasaṅkrānti*.

Figure 5: Schematic representation underlying the conversion of *tithis* to civil days. Here, C denotes the beginning of the lunar year (*Caitrādi*), M denotes the beginning of the solar year (*Meṣādi*), L denotes the beginning of the current lunar month (*māsādi*), and T denotes the current desired instant. Orange lines denoted by S_1 and S_2 represent mean sunrise times.

Obtaining the Avadhi and Cālaka

अवधिचालकानयनम्

गणे युगेन्दुविहृते लब्धं गतावधिर्भवेत् ।
शेषमिष्टावधेर्ज्ञेयः चालको दिवसादिकः ॥ २३ ॥ [अनुष्टुप्]

gaṇe yugenduvihṛte labdhaṃ gatāvadhir bhavet |
śeṣam iṣṭāvadher jñeyaḥ cālako divasādikaḥ || 23 || [*anuṣṭup*]

When the count [of civil days] is divided by 14 (*yugendu*), the quotient will be the elapsed *avadhi*s. The remainder should be known as the *cālaka* in days etc., of the desired *avadhi*.

The count of civil days elapsed in the current year computed in the previous verses can be further subdivided into an integer number of 14-day intervals, *avadhi*,[28] and a remainder of single days, called *cālaka*. This division of a sidereal year into 14-day intervals simplifies the process of tabulating values. Instead of a large table with 365 entries, two smaller tables, one with twenty-seven *avadhi*s as argument-values and another with 13 single-day argument-values can generate numerical values for any day of the year.

Obtaining the Mean Longitude of the Moon and its Anomaly
मध्यचन्द्रकेन्द्रानयनम्

इष्टावधिं संस्थितचन्द्रकेन्द्रौ
वर्षादिकेन्द्रेन्दुयुतौ विधेयौ ।
युतौ दिनाद्येन च चालकेन
तदेष्टकाले किल मध्यमौ स्तः ॥ २४ ॥ [उपजातिः]

iṣṭāvadhiṃ saṃsthitakendracandrau
varṣādikendrenduyutau vidheyau |
yutau dinādyena ca cālakena
tadeṣṭakāle kila madhyamau staḥ || 24 || [*upajātiḥ*]

The [longitude of the] moon and [its] anomaly found for the desired *avadhi* are added to [the longitude of] the moon and [its] anomaly [previously determined for] the beginning of the year. [Those] are increased by the [tabular values corresponding to] the *cālaka* [which is measured] in days etc. Indeed, the mean longitudes [of the moon and its anomaly] at the desired time are produced.

There are four steps involved in obtaining the mean longitude of the moon and its anomaly for any given day and time using tables:

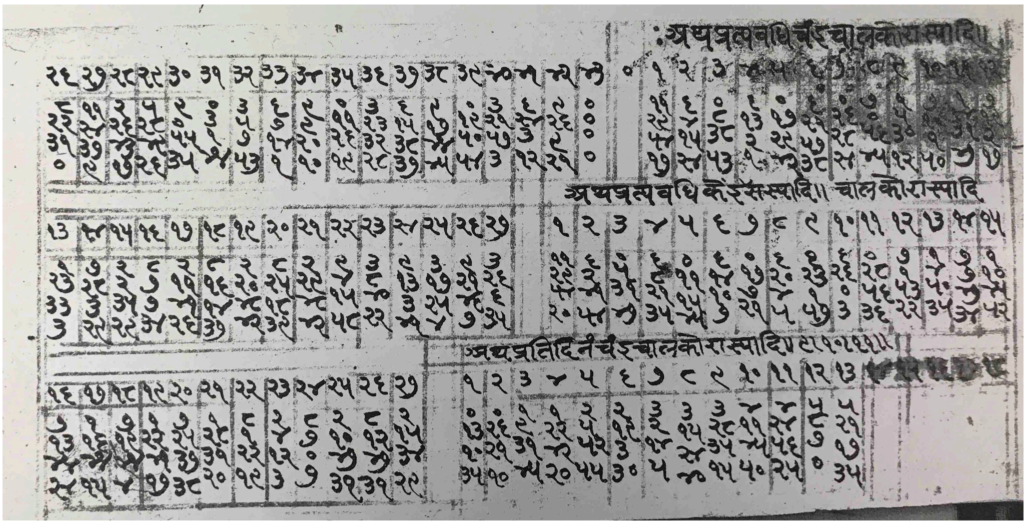
1. Selecting the value of the mean longitude at the beginning of the year (λ_0) for the moon (Table 9) and the anomaly (Table 10).
2. Selecting the value corresponding to the appropriate *avadhi* or elpased 14-day periods ($\Delta\lambda_a$) from Table 13.
3. Selecting the value corresponding to the *cālaka* or the number of days that have elapsed since the end of the last *avadhi* ($\Delta\lambda_d$) from Table 14.
4. Selecting the value corresponding to the number of *ghaṭikās* that has elapsed at the desired instant on that day ($\Delta\lambda_c$) for the moon only from Table 15.

28 The *avadhi* unit was used in various other table texts as well, including Anonymous of 1461 (Pingree 1968: 19), Anonymous III of 1578 (Pingree 1968: 54) *Khecaradīpikā* of Kalyāṇa (Pingree 1968: 62), Anonymous of 1704 (Pingree 1968: 65), *Karaṇakesarī* of Bhāskara II (Pingree 1968: 71).

The sum of the four values selected from the corresponding tables of the moon, and those of the lunar anomaly produces the mean longitude ($\bar{\lambda}$) of the moon and its anomaly respectively at a chosen instant on a desired day. That is,

$$\bar{\lambda} = \lambda_0 + \Delta\lambda_a + \Delta\lambda_d + \Delta\lambda_c. \quad (10)$$

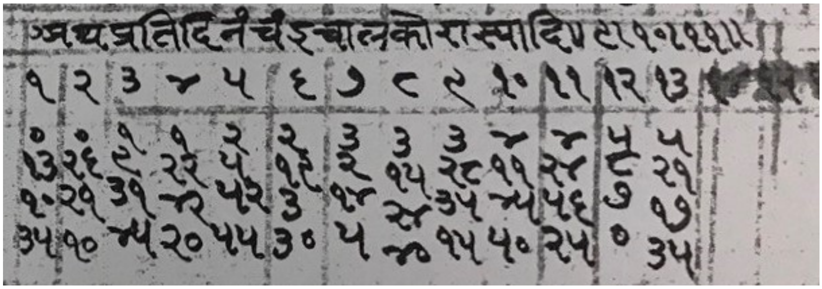
Of note is the fact that there is only a table for longitudinal displacement per *ghaṭikā* for the moon (see Table 15). This is because the lunar apogee only moves on average around 6 minutes per day; an additive quantity not significant enough to take into account for a fraction of a single day.



avadhi	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Lunar longitude	11	6	0	6	0	6	0	7	1	7	1	7	1	7	2	8	2	8	2	8	2	9	3	9	3	9	3
	29	4	8	13	17	21	26	0	5	10	14	19	23	28	2	7	11	16	20	25	29	4	8	13	17	21	26
	54	15	38	2	29	57	28	56	30	1	31	2	33	3	35	7	41	14	48	18	48	15	40	3	25	46	6
	17	24	53	1	42	38	24	45	12	50	47	17	3	29	29	34	26	37	42	39	42	58	22	41	4	7	35

avadhi	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Lunar anomaly	11	6	0	6	0	6	0	6	0	6	0	7	1	7	1	7	1	7	1	7	1	8	2	8	2	8	2
	29	2	5	8	11	14	17	20	23	26	28	1	4	7	10	13	16	19	22	25	28	1	4	7	10	12	15
	54	41	31	21	15	10	7	4	1	0	56	53	50	47	45	44	44	44	41	37	31	22	12	0	47	47	34
	20	54	47	35	45	7	21	5	57	3	36	22	35	34	52	24	15	4	17	38	20	19	3	7	31	31	29

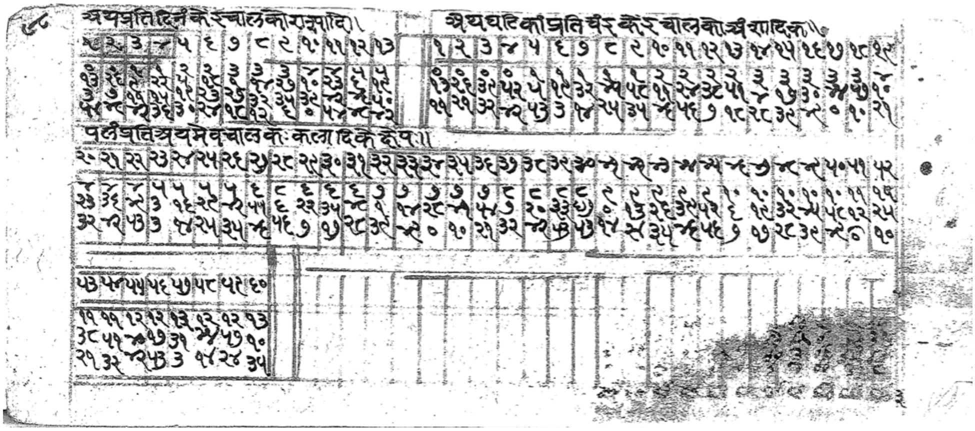
Table 13: [Top:] Mean longitudes of the moon for true sunrise in zodiacal signs, degrees, and sexagesimal fractional parts to two places for argument 1 to 27 *avadhis* of 14 days. [Bottom:] Corresponding lunar anomaly in zodiacal signs, degrees, and sexagesimal fractional parts to two places for argument 1 to 27 *avadhis* of 14 days. (MS **P**, f. 98r).



	Days	1	2	3	4	5	6	7	8	9	10	11	12	13
Lunar longitude		0	0	1	1	2	2	3	3	3	4	4	5	5
		13	26	9	22	5	19	2	15	28	11	24	8	21
		10	21	31	42	52	3	14	24	35	45	56	7	17
		35	10	45	20	55	30	5	40	15	50	25	0	35
Lunar anomaly		0	0	1	1	2	2	3	3	3	4	4	5	5
		13	26	9	22	5	18	1	14	27	10	23	6	19
		3	7	11	15	19	23	27	32	35	39	42	46	50
		54	48	42	36	30	24	18	12	6	0	54	48	42

Table 14: Table of *cālakas*. [Top:] Mean longitudes of the moon in zodiacal signs, degrees, and sexagesimal fractional parts to two places for argument 1 to 13 days (MS **P**, f. 98r). [Bottom:] Corresponding lunar anomaly in zodiacal signs, degrees, and sexagesimal fractional parts to two places for argument 1 to 13 days (MS **P**, f. 98v).

Table 13 provides the mean longitudes of the moon at true sunrises for each of the 27 *avadhi*s. Haridatta calculated these values by multiplying the mean daily motion of the moon (13;10,35) by 14, and then algebraically adding the product of the moon's mean daily motion and the sum of the equation of time (which comprises two components, namely *udayāntara* and *bhuja*ntara) and half-equation of daylight (*cara*). These corrections are explained in detail in verse 35.



ghaṭikā	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	0	0	0	0	1	1	1	1	1	2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5	5	6	8	6	6
Longitude	13	26	39	52	5	19	32	45	58	11	24	38	51	4	17	30	44	57	10	23	36	49	3	16	29	42	55	6	22	35
	11	21	32	42	53	3	14	25	35	46	56	7	18	28	39	49	0	10	21	32	42	53	3	14	25	35	46	56	7	17

ghaṭikā	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
	6	7	7	7	7	7	8	8	8	8	9	9	9	9	9	10	10	10	10	10	11	11	11	11	12	12	12	12	12	13
Longitude	48	1	14	28	41	54	8	20	33	47	0	13	26	39	52	6	19	32	45	58	12	25	38	51	40	17	31	44	57	10
	28	39	49	0	10	21	32	42	53	53	14	24	35	46	56	7	17	28	39	49	0	10	21	32	42	53	3	14	24	35

Table 15: Mean longitudes of the moon in degrees and sexagesimal fractional parts to two places for argument 1 to 60 *ghaṭikās* (MS **P**, f. 98v).

Obtaining the True Longitude of the Moon and its Daily Motion

स्फुटचन्द्रस्य तद्गतेश्च आनयनम्

केन्द्रस्थितभुजत्र्यंशात् कोष्ठस्थं सान्तरं फलम् ।
मध्यमे कारयेत् चन्द्रे स्वर्णं केन्द्रे तुलाजके ॥ २५ ॥ [अनुष्टुप्]

एवं स्पष्टो भवेत् चन्द्रः कोष्टस्था सान्तरा गतिः ।
मध्यमायां गतौ स्वर्णा केन्द्रे कर्किमृगादिके ॥ २६ ॥ [अनुष्टुप्]

लवाधस्थं कलाद्यं यत् अन्तरघ्नं विभाजितम् ।
षष्ट्या लब्धं फले युक्तम् एवं स्यात् सान्तरं फलम् ॥ २७ ॥ [अनुष्टुप्]

kendrasthitabhujatryaṃśāt koṣṭasthaṃ sāntaraṃ phalam |
madhyame kārayet candre svarṇaṃ kendre tulājake || 25 || [*anuṣṭup*]

evaṃ spaṣṭo bhavet candraḥ koṣṭasthā sāntarā gatiḥ |
madhyamāyāṃ gatau svarṇā kendre karkimṛgādike || 26 || [*anuṣṭup*]

lavādhasthaṃ kalādyaṃ yat antaraghnaṃ vibhājitam |
ṣaṣṭyā labdhaṃ phale yuktam evaṃ syāt sāntaraṃ phalam || 27 ||
[*anuṣṭup*]

[Entering the table] with a third part of the anomaly (*kendra*) reduced to the first quadrant[29] (*bhuja*), one should apply the equation of center (*manda-phala*) along with its difference situated in the table to the mean [longitude of] the moon, positively or negatively [depending upon whether] the lunar anomaly [lies in the six signs beginning with] Libra (i.e., 180 to 360 degrees) or Aries (i.e., 0 to 180 degrees), respectively.

In this way, the true longitude of the moon is produced. The correction to the rate of motion [of the moon] (*gatiphala*) along with [its] difference situated in the table [is applied] to the mean daily motion [of the moon], positively or negatively [depending upon whether] the lunar anomaly [lies in the six signs beginning with] Cancer (i.e., 90 to 270 degrees) or Capricorn (270 to 90 degrees), respectively.

Whatever is the [remainder] in minutes etc. (*kalādyam*), below the integral part (*lava*), [that] is multiplied by the difference and divided by sixty. The result is added to [the tabulated *manda*-]equation. In this way, the [tabulated *manda*-]correction along with [its] difference is produced.

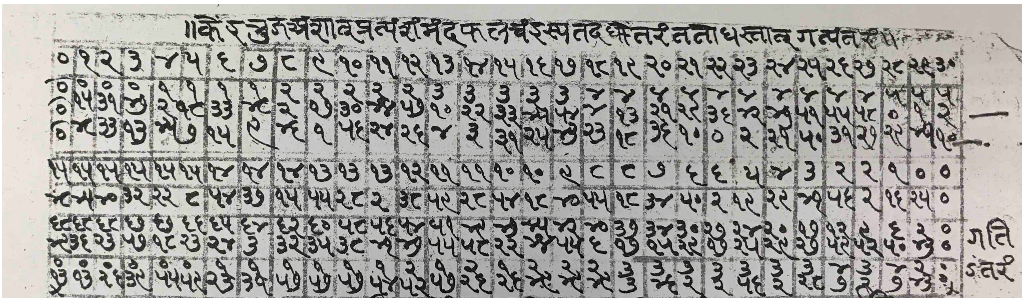
These verses describe the process of finding the true longitude of the moon and its true daily motion by applying a correction known as the *manda*-equation, the so-called equation of centre, and a corresponding motion correction, the *gatiphala*. These corrections are arranged in a single table (see Table 16). The table is made up of the following rows:

Argument : 0 to 30 units of lunar anomaly scaled by a third.
Row 1 : Correction to be applied to the moon's mean longitude in degrees, arcminutes, and arcseconds (*mandaphala*).
Row 2 : Differences between successive entries in row 1
Row 3 : Correction to be applied to the rate of motion (*gatiphala*), in arcminutes and arcseconds
Row 4 : Differences between successive entries in row 3

The maximum lunar *manda*-equation is $5^\circ;2,10$

The final verse in this group describes how to interpolate to determine non-tabulated values using the difference column. Of note is the specification to use the fractional part of the given argument (here expressed as *kalādi*) as the interpolation multiplier.[30]

29 For this process, see verse 29.
30 For similarly expressed interpolation algorithms in other table texts, see Montelle and Plofker (2018: 59–60).



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[*manda*-equation]	0	0	0	0	1	1	1	1	2	2	2	2	2	3	3	3
	0	15	31	47	2	18	33	48	2	17	30	44	57	10	22	33
	0	48	33	13	45	7	15	9	46	1	56	24	26	4	3	31
[Difference]	15	15	15	15	15	15	14	14	14	13	13	13	12	11	11	10
	48	45	40	32	22	8	54	37	15	55	28	2	38	59	28	54
Motion [correction]	68	68	68	67	67	66	65	64	62	60	58	56	54	51	49	47
	49	36	23	57	18	23	24	3	32	35	38	41	47	55	58	22
Difference	0	0	0	0	0	0	1	1	1	1	1	1	2	1	2	1
	13x	13	26	39	55	59	23	31	57	57	57	54	52	57	26	26

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
[*manda*-equation]	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5
	45	54	4	13	21	29	36	42	47	51	55	58	0	1	2
	25	43	23	18	36	10	0	2	21	50	31	27	29	45	10
[Difference]	10	9	8	8	7	6	6	5	4	3	2	2	1	0	0
	18	40	55	18	34	50	2	19	29	41	56	2	16	25	0
Motion [correction]	45	42	40	37	34	30	27	24	20	17	12	9	6	2	0
	44	55	6	17	15	29	17	25	29	27	59	52	50	43	0
Difference	2	2	2	3	3	3	3	3	3	3	4	3	4	2	0
	49	49	49	3	46	2	2	56	2	28	7	2	7	43	0x

Table 16: The lunar *manda*-equation in degrees, arcminutes, and arcseconds for argument 0 to 30 values of lunar anomaly scaled by a third, its successive differences in arcminutes and arcseconds, the lunar rate of motion correction (*gatiphala*) in arcminutes and arcseconds, and its successive differences in arcminutes and arcseconds (MS **P**, f. 98v).

The Mean Daily Motion of the Moon and its Anomaly

चन्द्रकेन्द्रयोः मध्यगतिः

मध्या गतिः शीतकरस्य पूर्ण-
नन्दाद्रयो बाणगुणाः कलाद्याः ।
केन्द्रस्य रामद्विरदाद्रयश्च
समुद्रबाणा गणकैर्निरुक्ताः ॥ २८ ॥ [उपजातिः]

madhyā gatiḥ śītakarasya pūrṇa-
nandādrayo bāṇaguṇāḥ kalādyāḥ |
kendrasya rāmadviradādrayaś ca
samudrabāṇā gaṇakair niruktāḥ || 28 || [*upajātiḥ*]

The mean daily motion of the moon is 790;35 (*pūrṇanandādri; bāṇaguṇa*) minutes etc., [and that] of the lunar anomaly is 783;54 (*rāmadviradādri; samudrabāṇa*) [in minutes, etc.,] [which] are stated by the mathematicians.

The mean daily motion of the moon and the lunar anomaly, precise only to seconds, are as follow:

$$\dot{\bar{\lambda}}_m = 790;35 \text{ minutes} = 13;10,35 \text{ degrees} \quad (11)$$

and

$$\dot{\bar{\lambda}}_k = 783;54 \text{ minutes} = 13;3,54 \text{ degrees.} \quad (12)$$

This is precise enough for use within a single day. This notably contrasts with the more precise values Haridatta has implicitly used to compute tabulated data for longer periods.

Reduction of Arcs to the First Quadrant
भुजकोट्यानयनम्

रामोनं विनिगदितो भुजस्तदूर्ध्वं
विश्लेष्यं रसभवनाद्रसाधिकं तत् ।
षड्कोनं यदि नवमाधिकं भचक्रात्
संशोध्यं भुजरहितं त्रिभं च कोटिः ॥ २९ ॥ [प्रहर्षिणी]

rāmonaṃ vinigadito bhujas tadūrdhvaṃ
viśleṣyaṃ rasabhavanād rasādhikaṃ tat |
ṣaṭkonaṃ yadi navamādhikaṃ bhacakrāt
saṃśodhyaṃ bhujarahitaṃ tribhaṃ ca koṭiḥ || 29 || [*praharṣiṇī*]

[If the value] mentioned is less than three [signs], it is a *bhuja* (i.e., an arc in the first quadrant). Greater than that (i.e., three signs) [it] is to be subtracted from six signs; if [it is] greater than six [signs], it is reduced by six signs; greater than nine [signs], it should be subtracted from the zodiac circle (twelve signs). The complement (*koṭi*) is three signs reduced by the *bhuja*.

This verse describes a method to reduce an arbitrary arc θ (*kendra*) to the first quadrant.[31] This is set out in Table 17.

31 This procedure is frequently included in astronomical texts. For instance,
त्र्यूनं भुजः स्यात् त्र्यधिकेन हीनं
भार्धं च भार्धादधिकं विभार्धम् ।
नवाधिकेनोनितमर्कभं च
भवेच्च कोटिस्त्रिगृहं भुजोनम् ॥
Karaṇakutūhala 2.4. (Rao and Uma 2008: 20).

bhuja = *bhuja*	when $0^\circ \leq \theta \leq 90^\circ$
bhuja = $180^\circ - \theta$	when $90^\circ < \theta \leq 180^\circ$
bhuja = $\theta - 180^\circ$	when $180^\circ < \theta \leq 270^\circ$
bhuja = $360^\circ - \theta$	when $270^\circ < \theta \leq 360^\circ$
koṭi = 90° − *bhuja*	

Table 17: Reducing an arc to the first quadrant (*bhuja*) and finding its complement (*koṭi*).

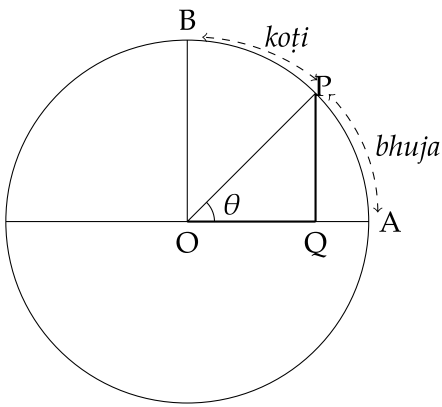


Figure 6: Representing the *bhuja* and *koṭi* as arcs in the first quadrant.

Description of the Table of True Solar Longitudes and Daily Motions

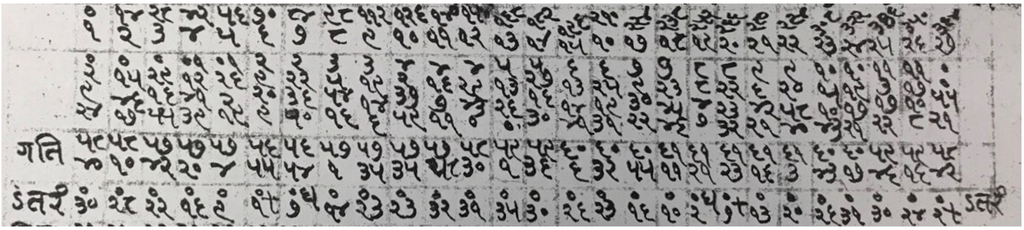
स्फुटसूर्यकोष्ठकविवरणम

चतुर्दशाहान्तरितः सबीजो दोःफलैः कृतः ।
भपङ्क्तिषु स्फुटः सूर्योऽप्यस्ति वर्षेशकालिकः ॥ ३० ॥ [अनुष्टुप्]

caturdaśāhāntaritaḥ sabījo doḥphalaiḥ kṛtaḥ |
bhapaṅktiṣu sphuṭaḥ sūryo 'pyasti varṣeśakālikaḥ || 30 || [*anuṣṭup*]

The true [longitude of] the sun [is found] in 27 (*bha*) table cells (*paṅkti*) with intervals of 14 days, [having been] corrected by the *bīja*-correction [and] by the *manda*-equation (*doḥphala*), indeed commensurate with the time of the lord of the year (i.e., at the time of mean *Meṣasaṅkrānti*).

Haridatta describes the features of the table that provides the true solar longitudes for each *avadhi* and corresponding true motion (see Table 18).



[Days]	0	14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308	322	336	350	364
[*Avadhi*]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	10	17	18	19	20	21	22	23	24	25	26	27
[Solar longitudes]	0	0	0	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	0
	2	15	29	12	26	9	22	5	19	2	16	29	13	27	13	25	9	23	8	22	6	20	5	19	3	17	0
	9	46	16	41	2	20	36	54	14	37	7	43	26	16	14	19	30	45	4	23	42	58	10	17	17	10	55
	24	17	55	39	19	9	50	16	6	59	11	0	0	30	41	31	22	46	7	32	21	40	43	21	22	8	21
Daily motion	58	58	57	57	57	56	56	57	57	57	57	58	59	59	60	60	60	61	61	61	61	61	60	60	59	59	58
	40	10	42	20	4	55	54	1	35	35	58	30	1	36	6	32	55	11	21	23	16	3	43	17	46	16	42
Difference	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30	28	22	16	9	1x	7_{dha}	14	18	23	32	31	35	30	26	23	16	10	2_{dha}	7x	13	20	26	31	30	24	2x

Table 18: True longitudes of the sun in zodiacal signs, degrees, arcminutes, and arcseconds for argument 1 to 27 *avadhi*s of 14 days, and true daily motions and their differences (MS **P**, f. 99r).

Argument : 0 to 364 days in multiples of 14 with the corresponding *avadhi* number from 1 to 27 below.

Row 1 : True solar longitude in signs, degrees, minutes, and seconds; from $0^r 2°; 9, 24$ for argument-value 1 (when the mean sun is at Aries 0°) to $0^r 0°; 55, 21$ for argument-value 27.

Row 2 : True daily motion in minutes and seconds.

Row 3 : Differences between successive entries in row 2.

Haridatta notes these true longitudes have been computed by applying the *manda*-equation (*doḥ-phala*) and *bīja* corrections, although he does not specify which *bīja*s have been used nor how they have been applied.[32] Here, *Meṣasaṅkrānti* is taken to be when the mean sun reaches Aries 0°. Since the table presents the true longitudes of the sun, it is evident that the 'lord of the year' day corresponds to the day on which the longitude of the mean sun is zero at *Meṣasaṅkrānti*.

Finding the True Longitude of the Sun and its Daily Motion for the Desired Day

इष्टदिने स्फुटसूर्यस्य तद्गतेश्चानयनम्

इष्टे गणे चालकसङ्गुणा गतिः
खेटस्य पूर्णर्तुहृता लवादिकम् ।

32 Pingree (1996) provides an overview of *bīja* corrections.

इष्टावधिस्थे विहितं धनर्णकं
गतेर्धनर्णत्वविधानतो ग्रहे ॥ ३१ ॥ [वासन्तिका]

iṣṭe gaṇe cālakasaṅguṇā gatiḥ
kheṭasya pūrṇartuhṛtā lavādikam |
iṣṭāvadhisthe vihitaṃ dhanarṇakaṃ
gater dhanarṇatvavidhānato grahe || 31 || [*vāsantikā*]

The daily motion of the sun on the desired day is multiplied by the *cālaka* and divided by 60 (*pūrṇartu*). [The result] in degrees etc. is applied to the [true longitude of the sun] corresponding to the given *avadhi* [from the table]. [For the computation] of the daily motion [on the desired day, the application of the difference either] positively or negatively is with respect to the nature of the increase or decrease [of the magnitude of the rate of motion] of the planet.

Next, Haridatta describes a technique for determining the true longitude of the sun as well as its daily motion on a desired day using the tables (see Table 18). For obtaining the true longitude, the daily motion associated to the current *avadhi* as given in row 3 in the table is to be multiplied by the *cālaka* value. The result is the true longitudinal displacement for the time interval associated with that *cālaka* value. As the tabulated motion is given in minutes and seconds, dividing through by sixty converts this quantity to degrees which can then be directly added to the true solar longitude for the given *avadhi*. Thus we get the true longitude of the sun on the given day.

For determining the true daily motion on a given day, the appropriate proportional part of the difference in successive motion values (row 4 of Table 18) is computed and applied positively or negatively to the corresponding true motion (row 3 in Table 18) depending on whether the rate of motion is increasing or decreasing. This has been indicated in the table by the abbreviated *nāgarī* character *dha* for *dhanam* 'positive' and a cross × to represent the abbreviated *nāgarī* character *ṛ* for *ṛṇaṃ* 'negative'. These symbols have been placed roughly at the transitions from increasing to decreasing values of daily motion in the fourth row.

The Importance of Determining the Positions of the Sun and Moon at Sunrise

सूर्योदये रविचन्द्राप्तिप्रयोजनम्

सूर्योदये प्रकर्तव्यौ रविचन्द्रौ यथोक्तवत् ।
तिथिनक्षत्रयोगानां घट्यादिज्ञानसिद्धये ॥ ३२ ॥ [अनुष्टुप्]

sūryodaye prakartavyau ravicandrau yathoktavat |
tithinakṣatrayogānāṃ ghaṭyādijñānasiddhaye || 32 || [*anuṣṭup*]

The [longitudes of the] sun and moon are to be calculated at sunrise as described earlier in order to obtain in *ghaṭī*s etc. [the remaining portions] of the *tithi*, *nakṣatra*, and *yoga*.

This verse introduces the *pañcāṅga* elements of *tithis*, *naksatras*, and *yogas* and confirms the solar and lunar positions are to be established at sunrise for the purposes of computing these calendrical elements.[33]

Obtaining the Current tithi at the Time of Sunrise

सूर्योदयकाले तिथ्यानयनम्

सूर्योनचन्द्रस्य लवा विभक्ताः
सूर्यैर्गतास्स्युः तिथयश्च भोग्यम् ।
वीनेन्दुभुक्त्या विकलीकृतं तत्
भक्तं भवेयुः तिथिगम्यनाड्यः ॥ ३३ ॥ [इन्द्रवज्रा]

sūryonacandrasya lavā vibhaktāḥ
sūryair gatāḥ syus tithayas ca bhogyam |
vīnendubhuktyā vikalīkṛtaṃ tat
bhaktaṃ bhaveyus tithigamyanāḍyaḥ || 33 || [*indravajrā*]

The longitude of the moon in degrees reduced by the longitude of the sun divided by 12 (*sūrya*) produces the elapsed *tithi*s. The part to be elapsed (i.e., the remaining portion of the current *tithi*) converted into minutes, divided by the daily motion of the moon reduced by that of the sun, produces the *nāḍī*s of the [current] *tithi* yet to be covered.

This verse outlines a procedure for calculating the elapsed *tithi*s in a lunar month as well as the remaining portion of the current *tithi* in *nāḍī*s from sunrise on a desired day. Let λ_m and λ_s denote the true longitudes of the moon and the sun, respectively, at sunrise. The difference between these two divided by 12 gives the integer elapsed *tithi*s τ and a remainder f:

$$\frac{\lambda_m - \lambda_s}{12} = \tau + \frac{f}{12}. \tag{13}$$

From the remainder, we can determine the remaining portion in *nāḍī*s of the current *tithi* ($\Delta\tau$) that is yet to elapse from sunrise. As per the prescription given in the verse, this be obtained as follows:

$$\Delta\tau = \frac{(12 - f) \times 60}{\dot{\lambda}_m - \dot{\lambda}_s}. \tag{14}$$

33 For further details on these time units, see Plofker and Knudsen (2011: 61–62).

Obtaining the Current nakṣatra and yoga at the Time of Sunrise
सूर्योदयकाले नक्षत्रयोगानयनम्

शशाङ्कलिप्ताः सरवीन्दुलिप्ताः
खखाष्टभक्ता भवतो भयोगौ ।
भोग्यं विलिप्तीकृतमिन्दुभुक्त्या
सेनेन्दुभुक्त्या विहृतं हि नाड्यः ॥ ३४ ॥ [उपजातिः]

śaśāṅkaliptāḥ saravīnduliptāḥ
khakhāṣṭabhaktā bhavato bhayogau |
bhogyaṃ viliptīkṛtam indubhuktyā
senendubhuktyā vihṛtaṃ hi nāḍyaḥ || 34 || [*upajātiḥ*]

The [longitude of the] moon expressed in minutes and the sum of the [longitudes of the sun and the moon] expressed in minutes divided by 800 (*khakhāṣṭa*) produces the [elapsed] *nakṣatra*s and *yoga*s [respectively]. The portion to be elapsed (*bhogya*) [of the current *nakṣatra* and *yoga*], converted into seconds, divided by the daily motion of the moon, and by the daily motion of the sun increased by that of the moon [respectively], indeed produces the *nāḍī*s [of the remaining portions].

The rules for determining the number of elapsed *nakṣatra*s and *yoga*s and the remaining portions of the current ones that are yet to elapse from sunrise are similar to the rules to compute *tithi*s. The time-unit *nakṣatra* here refers to the time it takes for the moon to advance a 27th part of the zodiac, namely $13^\circ;20 = 800'$. The time-unit *yoga* represents the time interval in which the eastwards progression of the sun and the moon add up to $13^\circ;20 = 800'$.[34]

To determine the number of elapsed *nakṣatra*s, the longitude of the moon (converted to minutes) is divided by 800. This yields an integer, the number of elapsed *nakṣatra*s, denoted by N, and a remainder f_N:

$$\frac{\lambda_m}{800} = N + \frac{f_N}{800}.$$

Similarly, the number of elapsed *yoga*s, denoted by Y, can be calculated:

$$\frac{\lambda_m + \lambda_s}{800} = Y + \frac{f_Y}{800}.$$

34 For further details on these elements of a *pañcāṅga*, see (Plofker and Knudsen 2011) and (Montelle and Plofker 2018: 30–31). For similar procedures in a related table text, see (Kolachana, Montelle, et al. 2018: 335–339).

In a manner similar to the previous verse for determining the remaining portion of the *tithi*, the remaining portions in *nāḍī*s of the current *nakṣatra* (ΔN) and *yoga* (ΔY) that are yet to elapse since sunrise can then be obtained as follows:

$$\Delta N = \frac{(800 - f_N) \times 60}{\dot{\lambda}_m} \tag{15}$$

and
$$\Delta Y = \frac{(800 - f_Y) \times 60}{\dot{\lambda}_m + \dot{\lambda}_s}. \tag{16}$$

Deśāntara and Other Corrections

देशान्तरादिसंस्काराः

देशान्तरं फलं यातं चरं भुजफलं तथा ।
वर्षेशनाड्यां स्वमृणं कर्त्तव्यमवधौ स्फुटम् ॥ ३५ ॥ [अनुष्टुप्]

deśāntaraṃ phalaṃ yātaṃ caraṃ bhujaphalaṃ tathā |
varṣeśanāḍyāṃ svamṛṇaṃ karttavyam avadhau sphuṭam ‖ 35 ‖ [*anuṣṭup*]

[The corrections, namely] *deśāntara*, *yātaphala*, *cara*, and *bhujaphala*, should be applied positively or negatively to the *nāḍī*s of the lord of the year [as well as] to each *avadhi*. The true [solar position at the true sunrise for a given locality is obtained].

Here Haridatta lists a set of four corrections,[35] that are used to determine the true longitude of the sun at the true sunrise for any given locality. These are:

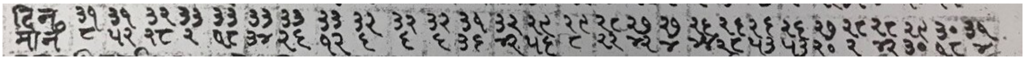
***deśāntara*:** accounts for the variation in sunrise time between an observer on the meridian of zero longitude and an observer at some other longitude situated to the east or west of it where the sunrise will occur earlier or later.

***cara*:** also known as the ascensional difference; accounts for the time difference between sunrise observed at the equator (zero latitude) and that observed by an observer having a non-zero latitude, i.e., to the north or south of it.

***yāta-phala*:** also known as the *udayāntara* (rising-difference) or *prāṇakalāntara*; accounts for the time difference between the passage of the mean and the true sun at the observer's meridian due to the obliquity of the ecliptic.

***bhuja-phala*:** also known as *bhujāntara*; accounts for the time difference between the passage of the mean and the true sun at the observer's meridian due to eccentricity of the sun's orbit.

35 For more details see Ramasubramanian and Sriram (2011: 81–82) and Montelle and Plofker (2018: 50).



dinamānam	31	31	32	33	33	33	33	33	32	32	32	31	32	29	29	28	27	27	26	26	26	26	27	28	28	29	30	31
	8	52	28	2	18	34	26	12	6	6	6	36	42	56	8	22	42	4	44	28	53	53	20	2	42	30	18	4

Table 19: Length of daylight table in *ghaṭikās* and *vighaṭikās* for argument 1 to 27 *avadhi*s (MS **P**, f. 99v). These numerical values are somewhat corrupt. Pingree (1968: 58) has proposed a corrected table.

These four corrections are commonly tabulated together, as they have been in one of the manuscripts of the *Jagadbhūṣaṇa* (see Table 20). In the header, the paratext reads:

> *idaṃ catuṣṭayaikyam abdapaghaṭikā<sa>dhanarṇaṃ karttavyam* |
> *pratyavadhi abdapaghaṭikāḥ bījasaṃskṛtāḥ bhavanti* |
> This sum of four corrections is to be applied positively or negatively to the *ghaṭikās* of the lord of the year. For each *avadhi* the lord of the year *ghaṭikās* are corrected by the *bījas*.

The contents of the table are:

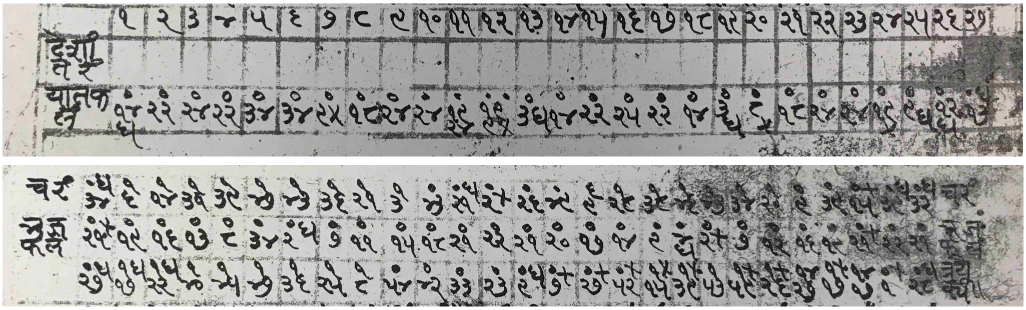
- **Argument** : 1 to 27 *avadhis*.
- **Row 1** : A row of empty cells with row-header *deśāntara*.
- **Row 2** : The *yāta-phala*.
- **Row 3** : The *cara*.
- **Row 4** : The *bhuja-phala*.
- **Row 5** : The *trayaikya* ('sum of three'); the algebraic sum of the values in the previous three rows.

MS **P** also includes a table that provides the length of daylight for each *avadhi* (see Table 19). From this, the latitude underlying these tables can be reconstructed as $\phi \approx 24^{\circ}$ which likely corresponds to Udaipur (for discussion, see Section 1).

Concluding Remarks
अधिकारसमाप्तिवचनम्

> श्रीमज्जगत्सिंहधराधिपस्य
> प्रीत्यै जगद्भूषणसंज्ञकेऽस्मिन् ।
> कारापिते श्रीसबलेन राज्ञा
> पूर्णो रवीन्दुस्फुटताधिकारः ॥ ३६ ॥ [इन्द्रवज्रा]

> *śrīmajjagatsiṃhadharādhipasya*
> *prītyai jagadbhūṣaṇasaṃjñake 'smin* |



avadhi	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
deśāntara																											
yāta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14_{dha}	22	24	22	34	34_{dha}	9_{x}	18	24	24	19	9_{x}	3_{dha}	14	22	25	22	14	3_{dha}	8_{x}	18	24	24	19_{x}	9_{dha}	12	13_{dha}
cara	0_{dha}	1	1	1	1	1	1	1	1	1	0	0_{dha}	0_{x}	0	0	6	1	1	1	1	1	1	0	0	0_{x}	0_{dha}	0_{dha}
	34	56	14	31	39	47	43	36	21	3	43	21	2	26	49	9	28	38	46	43	34	20	59	39	15	9	32
bhujaphala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	19	16	13	08	03	02	07	11	15	18	21	22	21	20	17	14	09	04	02	07	12	16	19	21	22	21
trayaikya	0_{dha}	1	1	1	1	1	1	1	1	0	0	0	0	0_{dha}	0_{x}	0	0	1	1	1	1	1	1	1	1	0_{x}	0_{dha}
	27	19	22	40	45	47	36	25	8	54	42	33	23	9	7	27	52	15	39	53	59	26	27	17	17	1	28

Table 20: Time corrections in *ghaṭikās* and *vighaṭikās* for argument 1 to 27 *avadhi*s of 14 days (MS **P**, ff. 99r–99v). For an analysis of this table with corrected values, see Pingree (1968: 57–58).

kārāpite śrīsabalena rājñā
pūrṇo ravīndusphuṭatādhikāraḥ || 36 || [*indravajrā*]

For the joy of his excellency Jagatsiṃha, the protector of the world, in this [composition] named *Jagadbhūṣaṇa*, which was commissioned by King Sabala, the chapter on the true [longitudes and motions] of the sun and moon is complete.

ACKNOWLEDGEMENT

ONE OF THE AUTHORS, namely Keshav Melnad, would like to express his gratitude to the Indian Institute of Technology, Gandhinagar, for supporting his post-doctoral research work making an in-depth study of the text *Jagadbhūṣaṇa* under the aegis of the "History of Mathematics in India" (HoMI) project.

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