Journal of Astronomical History and Heritage, 27(1), 209–218 (2024).

GRAHAṆAMUKURA – A SIXTEENTH CENTURY INDIAN MANUAL FOR THE CALCULATION OF ECLIPSES

B.S. Shylaja
Jawaharlal Nehru Planetarium, Bengaluru, India.
E-mail: shylaja.jnp@gmail.com

Ramakrishna Pejathaya
Centre for Indian Knowledge Systems, Chanakya University, Bengaluru, India.
E-mail: b.ramakrishnap@gmail.com

and

Seetharama Javagal[1]
Deceased.

Abstract: This is a study of a rare seventeenth century palm-leaf manuscript named the *Grahaṇamukura*, which has been carefully preserved in a private collection for more than 400 years. This manuscript was used to calculate eclipses, and has bilingual text, with verses in Sanskrit and a commentary in Kannaḍa, a southern Indian language. It is a handy manual for the prediction of eclipses following the methods prescribed in treatises.

In the absence of the name of the author anywhere in the text, we conjecture that it was written by the father–son duo, Demaṇa Joyisaru and Śaṅkaranārāyaṇa Joyisaru of Sringeri. In this paper the contents of the text are summarized.

[5]
Keywords: Astronomy texts in Kannaḍa, Sringeri (Śṛngeri), eclipse calculations, *Grahaṇamukura*, palm leaf manuscripts, Viddana, Shankaranarayana (Śaṅkaranārāyaṇa) Joyisaru, Demana (Demaṇa) Joyisaru

1 INTRODUCTION

The rich heritage of knowledge and culture in India has produced a large number of scholars over the last 2000 years. We are fortunate that ancient knowledge has been preserved by our ancestors through the millennia. The manuscripts in repositories of astronomy are invariably in Sanskrit, and in the form of verses, composed in metrical form for ease of transmission of knowledge orally. The metrical form can also help us in tracing the missing words or letters, and even in identifying the errors (if any) in the copied manuscripts. This knowledge has been transmitted since time immemorial through the oral tradition. There were *Gurukulas*—a type of residential school with dedicated teachers—where this knowledge was imparted to students. Knowledge also was passed on within the family, from father to son, then to his son, and so on. These scholars prepared handy manuals for day-to-day calculations, incorporating the latitude and longitude of the location.

In this paper we discuss one such manual, the *Grahaṇamukura*, which was prepared exclusively for the prediction of eclipses. It was written in Kannaḍa, a regional language of Southern India.

2 THE AUTHOR

We were able to trace the lineage of the scholar Kulapati Śaṅkaranārāyaṇa Joyisaru (1903–1998) of Sringeri. This town (13.4198° N, and 75.2567° E), shrouded in the forests of South India, is well known for its traditional and scholastic environment. Kulapati Śaṅkaranārāyaṇa Joyisaru studied *Jyotiṣa* at the Maharaja's Sanskrit College in Mysore in 1925. He was an *Āsthāna Vidvān* (Royal Scholar) at Sri Sringeri Mutt. He was conferred the title of 'Kulapati' by Sri Sri Abhinava Vidyateertha Swamiji, the 35th *pīṭhādhipati* (chief pontiff) of Sri Sringeri Sharada Peetham (the religious institution) in appreciation of the services he rendered as a teacher at the educational institution Śrī Sadvidyā-Sanjīvinī Saṃskṛta-Pāṭhaśālā in Sringeri for nearly 40 years. This included 11 years as head of the Pāṭhaśālā.

Kulapati Śaṅkaranārāyaṇa Joyisaru's ancestors were scholars in *Jyotiṣa*. In particular, the father–son duo of Demaṇa Joyisaru and Śaṅkaranārāyaṇa Joyisaru, who flourished in the latter half of the sixteenth century and early part of the seventeenth century, were eminent scholars in *Jyotiṣa*, and had written commentaries on some of the *Jyotiṣa granthas* available at that time. The commentaries are in Sanskrit / Kannaḍa written on palm leaves in the *Nandināgarī* script, which is not in use today. These palm leaf manuscripts have been preserved in the family by successive generations over a period of 400 years.

59ದವ್ರೊತ್ತುವಿಡಿದ-ಅಡಕೇಮರ ಷಿಂ ಕಾಶ್ಯಪಗೋತ್ರದವೂಧ್ಯಂದಿನ
60ಶಾಖೆಯುಕಾತ್ಯಾಯನಸೂತ್ರದದೇವಣಜ್ಯೋತಿಷರಮಕ್ಕಳುಶಂ
61ಕರನಾರಾಯಣಜ್ಯೋತಿಷರಿಗೆಕೆದ್ದಸೆಬೊಂಮಣನಲ್ಲಿಭತ್ತಖಂ

Figure 1: Photographs of the stone inscription and the transcription in Kannaḍa giving details of the authors who were awarded land grants (photographs courtesy: Seetharama Javagal).

A unique document which throws light on the dates and scholarship of the father–son duo is a stone inscription preserved in the premises of Sringeri Mutt (see Figure 1). It states that Sri Abhinava Nṛsimha Bhāratī, the 24th *pīṭhādhipati* of Sringeri established an *agrahāram* – *Nṛsiṃhapura* – near Sringeri on *Bhādrapada Śuddha Daśamī, Śobhakṛt Saṃvatsara, Śālivāhana Śaka* 1525 (1603 CE) and granted lands to Brahmins of various lineages (*gotra*s and *sutras*). Śaṅkaranārāyaṇa Jyotiṣī son of Demaṇa Jyotiṣī is one of the beneficiaries (Joyisaru is the Kannaḍa version of the Sanskrit word Jyotiṣī).

Based on the available records, the *vaṃśavṛkṣa* (family tree) of the family has been prepared, and published by Shylaja and Javagal (2020). The earliest known ancestor is Devaru Joyisaru (~1500 CE), followed by his son, Demaṇa Joyisaru and grandson, Śaṅkaranārāyaṇa Joyisaru, up to the namesake Kulapati Śaṅkaranārāyanā Joyisaru (1903–1998).

Kulapati Śaṅkaranārāyaṇa Joyisaru had inherited from his ancestors over 50 bundles of palm leaf manuscripts, besides over 100 handwritten / printed books on *Jyotiṣa*, *Śāstra*s, *Sāhitya* and devotional topics. Added to this were the books on *Jyotiṣa* and *Dharma Śāstra* procured by him during his student days and later. Towards the end of his life, he donated the bulk of the palm leaf manuscripts and books to Sri Sringeri Mutt, so that they are accessible to persons interested in the subjects. He had retained only five bundles of palm leaf manuscripts as family heritage and handed them over to his son for preservation.

One of the bundles contains commentaries on the *Siddhānta Jyotiṣa granthas* (treatises) written by his ancestors. They are the

(1) *Grahaṇamukura*, or Mirror to Eclipses, by Demaṇa Joyisaru (s/o Devaru Joyisaru).
(2) *Tantradarpaṇa*, or Mirror of *Tantra*, by Śaṅkaranārāyaṇa Joyisaru (s/o Demaṇa Joyisaru).
(3) *Karaṇābharaṇam*, or Ornament of *Karaṇa*, by Śaṅkaranārāyaṇa Joyisaru.
(4) *Gaṇitagannaḍi*, or Mirror of Mathematics, by Śaṅkaranārāyaṇa Joyisaru.
(5) *Grahaṇaratna*, or Jewel of Eclipses, by Śaṅkaranārāyaṇa Joyisaru.

These *granth*as also were written on palm leaves in *Nandināgarī* script, and have been given preservative treatment and digitized. The texts have been transliterated from *Nandināgarī* to *Devanāgarī* / Kannaḍa as the case may be, and saved in Unicode on computers.

It was the normal practice among the authors of yore to mention their place, *gotra* (lineage), father`s name and their own name either at the beginning (*maṅgalācaraṇa*) and / or in the colophon of their manuscripts. In the *granth*as written by Śaṅkaranārāyaṇa Joyisaru son of Demaṇa Joyisaru, he mentions his place (Śṛṅgapura), his father`s name (Demaṇa Joyisaru), his own name, and the year. Similar information is provided below for the four other manuscripts mentioned above.

(2) *Tantradarpaṇa*: the commentary is in Sanskrit on Viddaṇācārya`s *Vārṣikatantra* Śālivāhana Śaka 1523 (1601 CE).
(3) *Karaṇābharaṇam*: the commentary is in Sanskrit Brahmadeva`s *Karaṇaprakāśa* Śā.Śa 1525 (1603CE), edited by Dr. K.

Mahesh and Seetharama Javagal and published by Rastriya Sanskrit Vidyapeetha, Tirupati, in 2020.

(4) *Gaṇitagannaḍi*: the commentary is in Kannaḍa on Viddaṇācārya`s *Vārṣikatantra*. Śā. Śa. 1526 (1604 CE), with a translation into English and mathematical analysis by Dr B.S. Shylaja and Seetharama Javagal, and published by Navakarnataka Publications, Bengaluru, in 2021.

(5) The *Grahaṇaratna:* authored by Śaṅkaranārāyaṇa Joyisaru himself consisting of 67 verses. Year of composition not mentioned.

In the *Grahaṇamukura*, there is no specific mention of the name of the author or his place of residence, or the year of writing. In the absence of any information on the author in the *grantha*, we have to go by conjecture and assumptions. Since all the five *grantha*s are found in one bundle of manuscripts, and, since four of them have the name of the author as Śaṅkaranārāyaṇa Joyisaru s/o Demaṇa Joyisaru, it is probable that the remaining one was also written by the same authors. But Śaṅkaranārāyaṇa Joyisaru is very categorical in mentioning his name, his father`s name and the place, so it is unusual that he does not mention his name in the *Grahaṇamukura*.

The next possibility is that his father, Demaṇa Joyisaru, authored this *granthi*. Firstly, the *Grahaṇamukura* is the first *grantha* in the bundle, followed by the *Tantradarpaṇa* (1601 CE), the *Karaṇābharaṇam* (1603 CE), the *Gaṇitagannaḍi* (1604 CE) and the *Grahaṇaratna.* Secondly, the *Grahaṇamukura* starts with the following benediction:

श्रीगणाधिपतये नमः श्रीसरस्वत्यै नमः
श्रीगुरुभ्यो नमः
श्रीविद्याशङ्करराय नमः श्रीनृसिंहभारतीगुरुभ्यो नमः
निर्विघ्नमस्तु
यस्य निश्वसितं वेदा यो वेदेभ्योऽखिलं जगत् ।
निर्ममे तमहं वन्दे विद्यातीर्थमहेश्वरम् ॥
śrīgaṇādhipataye namaḥ śrīsarasvatyai
namaḥ śrīgurubhyo namaḥ
śrīvidyāśaṅkarāya namaḥ
śrīnṛsiṃhabhāratīgurubhyo namaḥ
nirvighnamastu
yasya niśvasitaṃ vedā yo vedebhyo'khilaṃ jagat |
nirmame tamahaṃ vande
vidyātīrthamaheśvaram ||

Śrī Vidyātīrtha (1229–1333 CE) cited in the above verse was the 10th *pīṭhādhipati* (chief pontiff) of Sringeri *Pīṭham*. He was a *mahāyogi* and attained *samādhi* through the *lambikā yoga*. At the place where he attained *samādhi*, a *śivaliṅga* had appeared, and came to be known as Vidyāśaṅkara. His successors constructed a temple over the *śivaliṅga* in 1338, popularly known as the Vidyashankara Temple, which is an architectural marvel in the Hoysala and Dravidian tradition. Even to this day, the *Śrīmukha* (emblem) of the Śṛingeri *Pīṭham* contains the name *Vidyāśaṅkara*.

The author`s salutation to Sri *Vidyāśaṅkara* and the *Vidyātīrthamaheśvaram* confirms the *grantha* is of Śṛingeri origin; further it provides the possible date of the composition by the salutation to Śrī Nṛsiṃhabhāratī. In the unbroken chain of Sringeri *pīṭhādhipati*s, the following *pīṭhādhipati*s had the name 'Nṛsiṃhabhāratī':

21st. Śrī Nṛsiṃhabhāratī – III (1560–1573)
22nd.Śrī Nṛsiṃhabhāratī - IV (1573–1576)
23rd. Śrī Nṛsiṃhabhāratī - V (1576–1599)
24th. Śrī Abhinava Nṛsiṃhabhāratī (1599–1623)

This period of the 24th coincides with the lifetime of Demaṇa Joyisaru and his son Śaṅkaranārāyaṇa Joyisaru. Furthermore, Śaṅkaranārāyaṇa Joyisaru, in the colophon of his *grantha*s, reverentially refers to his father as वासवगुरुसमानदेमणज्योतिर्विद (*vāsavaguru-samāna-demaṇa-jyotirvida*), Bṛhaspati-like Demaṇa, who is very knowledgeable in *Jyotiṣa*. In all probability, Demaṇa Joyisaru himself taught *Jyotiṣa* to his son Śaṅkaranārāyaṇa, who has four *grantha*s to his credit. Moreover, we should note the similarity in the Kannaḍa language employed in the commentary in the *Grahaṇamukura* and the *Gaṇitagannaḍi*.

Dikshit (1896) visited various institutions and *Jyotiṣa* scholars all over India, and prepared a catalogue of *Jyotiṣa grantha*s available in the country. He mentions Viddaṇācārya as the author of the *Vārṣikatantra*, but he could not determine the exact period when it was written. He also mentions in passing that Viddaṇa had also written the *Grahaṇamukura*. Apparently, Dikshit had not seen the text of the *Grahaṇamukura* himself, but used the mention of it in the catalogue by Oppert (1885).

Dikshit (1896) is of the opinion that Viddaṇa belonged to a place near Dharwad (15.460252 N and 75.010284 E) in Karnataka. Keeping this in mind, we approached two Institutions, Bhandarkar`s Oriental Research Institute in Pune and the Oriental Research Institute in Mysore, neither of which had copies of the *Grahaṇamukura* in their collections.

Under the heading Shankaracharya Swami Matha of Sringeri, the Oppert (1885) Catalogue of manuscripts mentions at page no. 286 and sl. no. 4573 the *Grahaṇamukura*, but the name of the author is not mentioned. Our enquiry with Advaita Shodha Kendra from Sringeri, revealed

that they do not have the *Grahaṇamukura* in their collection. So, to the best of our knowledge, ours is the only available manuscript of the *Grahaṇamukura*.

This opens different possibilities:

- There are two different texts having the same name *Grahaṇamukura*, one written by Viddaṇa and the other written by Demaṇa. This probability cannot be ruled out because Sūryadeva Yajva of Coḷadeśa wrote a *grantha* titled the *Jātakālaṅkāra* in the thirteenth century, while Gaṇeśa Daivajña from the Konkan region in Maharashtra also wrote a *grantha* titled *Jātakālaṅkāra* in the sixteenth century, which is different from the earlier one.
- Viddaṇa has written the Sanskrit verses, and Demaṇa has written the commentary in Kannaḍa.
- Pingree (1994, CESS series A Volume 5) lists under Viddaṇa (*Grahanamukura*) Property of Mahadeva Joyisa of Sringeri. Mahadeva Joyisa referred to here is probably the grandfather of Kulapati Shankaranarayana Joyisaru (1903–1998). CESS does not mention the *Grahaṇamukura* of Viddaṇa.
- Viddaṇa has mentioned his *gotra* (*Kauṇdinya*), his father`s name (Mallaṇa), and his own name at the beginning of the *Vārṣikatantra*, while these are not mentioned in the *Grahaṇamukura*.
- Viddaṇa flourished around 1350 CE (Pingree, 1994). The *ahargaṇa* calculations in the *Grahaṇamukura* give the impression that it was written around 1468 CE; hence the possibility of both Viddaṇa and Demaṇa having written the Sanskrit text is ruled out.

Demaṇa Joyisaru has made a copy of the *Jātakālaṅkāra*, authored by Sūryadeva Yajvā (b. 1191 CE) of Coḷadeśa, which ends as follows.

इति श्रीसूर्यदेवसोमसुद्विरचिते
श्रीपतिपद्धतिव्याख्यानेजातकालङ्कारे
प्रकीर्णकाध्यायोऽष्टमः |
इति सम्पूर्णः जातकालङ्कारः ।
स्वस्तिश्रीजयाभ्युदयशालिवाहनशके 1529 ನೇ
ಪ್ಲವಂಗ ಸಂವತ್ಸರದ ಮಾಘ ಶುದ್ಧ 1
ಶುಕ್ರವಾರದಲ್ಲಿ ಸಿಂಗೇರೀ ದೇವರು
ಜೋಯಿಸರ ಮಗ ದೇಮಣ ಬರದ
ಜಾತಕಾಲಂಕಾರದ ಪುಸ್ತಕಕ್ಕೆ ಮಂಗಲ
ಮಹಾ ಶ್ರೀ ಶ್ರೀ ಶ್ರೀ || ಶುಭಮಸ್ತು ||

iti śrīsūryadevasomasudviracite
śrīpatipaddhativyākhyāne jātakālaṅkāre
prakīrṇakādhyāyo'ṣṭamaḥ |
iti sampūrṇajātakālaṅkāraḥ |
svastiśrījayābhyudayaśālivāhanaśake
1529 plavaṅga saṃvatsara māgha
śuddha …

This concluding sentence in Kannaḍa states that the *Jātakālaṅkāra* was written by Demaṇa, son of Devaru Joyisaru of Sringeri, the date of completion being Śā.Śa. 1529 (1608 CE), *Plavaṅga saṃvatsara*, *Māgha śuddha prathamā* (Friday).

The name of the *saṃvatsara* is a very useful tool to fix the date. It is a cycle of 60 years in use even today. This, and the dates of the *Karaṇābharaṇam* and the *Gaṇitagannaḍi* suggest Demaṇa Joyisaru`s time of around 1550 to 1620 CE (approximately). We show in the next section that the epoch for calculations chosen is 1578 CE and therefore fix the date of the work to the last quarter of the sixteenth century.

In the text available with us, every chapter ends with इति श्रीग्रहणमुकुरव्याख्याने (*iti śrīgrahaṇamukuravyākhyāne*) as in इति श्रीग्रहणमुकुरव्याख्याने परिलेखनाध्यायः सप्तमः ।। *iti śrīgrahaṇamukuravyākhyāne parilekhanādhyāyaḥ saptamaḥ*), which translates as 'the seventh chapter called *parilekhana,* of the commentary on *Grahaṇamukura*'. It is probable that the original text is named the *Grahaṇamukura*, and that the commentary in Kannaḍa has not been given a separate name.

In conclusion,

- Sringeri is the origin of the *Grahaṇamukura*.
- It has not moved out of Sringeri.
- There are only two copies of the *grantha*, both with the *Jyotiṣa* family of Sringeri.
- Demaṇa Joyisaru of Sringeri was an eminent *Jyotiṣa* scholar, who flourished in the latter half of sixteenth century and early seventeenth century.
- Demaṇa Joyisaru was patronized by succesSsive Sringeri *Pīṭhādhipati*s during his lifetime.

Most likely Demaṇa Joyisaru, the son of Devaru Joyisaru, of Sringeri, is the author of at least the Kannaḍa commentary of the *Grahaṇamukura*, if not the entire text, including the Sanskrit verses.

All of these are now available to the international academic community, and we consider it a privilege that we can now place this hitherto unpublished ancient text in the public domain for the benefit of knowledge-seekers.

3 THE TEXT

The word *Grahaṇamukura* means 'mirror of eclipses', and the text is written on about 16 palm leaves. The first palm leaf, which has the title of the book in one corner, is reproduced in Figure 2. The author explains that the procedure finally leads to the depiction of the eclipse as though you are seeing it in a mirror.

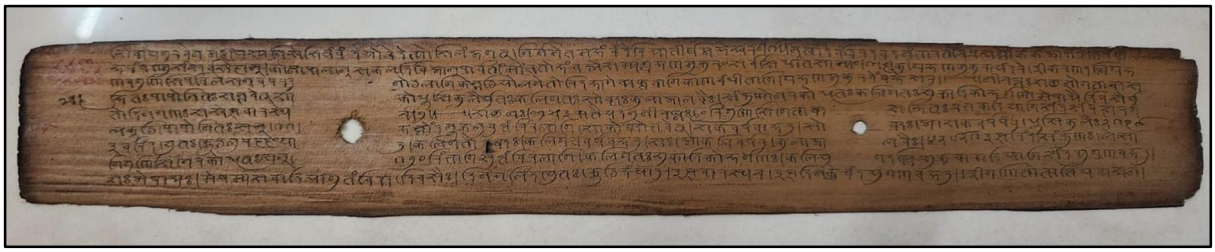

Figure 2: The first palm leaf of the manuscript; the name is inscribed in the corner; the script is *nandināgari* (photograph courtesy: Seetharama Javagal).

The text is a primer for the calculation of eclipses. The procedures adopted for the *karaṇa* text follow the others in the same order. It is divided into seven chapters. The first one to get the mean values of the Sun, the Moon and the node, *Rāhu,* is very brief with 16 verses. He explains the procedure in very crisp sentences. A comparison with the method of the *Āryabhaṭīyam* is discussed.

There are several details told very briefly in this commentary. The foremost task for the astronomer is to calculate the number of days elapsed from the Kali epoch. Conventionally the count used is a cycle of 60 years (with names) from the epoch of the *Śālivāhana Śaka* (*Śā.Śa*) which corresponds to 78 CE. Here he specifies that this epoch corresponds to Yudhiṣṭhira years of 3044 and *Vikrama saṃvat* 135. He provides a rule of thumb for calculating the *dyugaṇa* (total number of days) from the epoch of the *Kali* year.

We need to know the number of years that have elapsed as well as the number of days in a year. For the year corresponding to the beginning of *Śālivāhana* it was *Bahudhānya*, which in the list of 60 is the 12th. We need to start from the first one, *Prabhava*, which is 11 years prior to the *Śaka* epoch (of 78 CE). Since 25 cycles of 60 years have elapsed for the current year, we get 1500. However, accounting for *Bahudhānya,* of 78 CE, we have to subtract 11. This takes us to the beginning of the current cycle. The current *saṃvatsara's* serial number is now added to get the total number of years.

This helps us to estimate that the book was written somewhere around *Śaka* 1500 which corresponds to 1578 CE. Considering the other books written in 1603 and 1604 CE we may attribute the same father–son duo as authors of this work also.

For all calculations the numeral 1668863 representing the number of days that have elapsed is used. This is for the mid night of that Thursday, for which he states "… the *dhruvakas* of Ravi, Candra, *Ucca* and *Rāhu* have been calculated by me [which are] as good as those from established *siddhānta.*" This number also concurs with the time calculated above.

The *ahargaṇa* number is arrived at using the number of years from 78 CE. This is again provided as a thumb rule: multiply the number of years by 43831 and divide by 120. The rationale is derived from the *Sūrya Siddhānta* which states that the number of revolutions of the Sun in a *mahāyuga* of 1577917828 *sāvana* days (civil days) is 4320000, which implies that the duration of the year is 365 days 15 *ghaṭi* 31 *vighaṭi* 31 *pare* and 24 *tatpare*. For 120 years this works out to be 43831 days, approximating the year to 365 days 15 *ghaṭi* and 30 *vighaṭi*.

The second chapter on getting the true values has 10 verses and is palatable only for those who have understood the *Siddhānta*. This procedure is similar to the one used in the *Gaṇitagannaḍi*. The reason for the precession of equinoxes is attributed to (a fictious planet) *Ayanagraha*, which has a specific periodicity. The slow variation was attributed to a planet (in the sense of a variable) and the position was calculated for the specific year. This is an understandable situation since the periodicity is 26000 years.

The third chapter with 13 verses deals with the details of getting the various corrections to fix the position in the sky for the instant of New Moon / Full Moon, the time in terms of *lagna* (the ascendant) for the location of the observer. Again, in the absence of any theoretical explanation, this will be understood only by those who have studied the texts thoroughly. All corrections are for Sringeri.

The fourth chapter on lunar eclipses with 17 verses is very elaborate. The procedure is same as described in the *Karaṇakutūhalam* of Bhāskarācārya (Balachandra Rao and Uma, 2008). It starts by deriving the possibility of eclipses and calculates up to the *valana*, the points and timings of contact, durations of partial and total phases. The visibility of the points of contact and the position angle on the disc of the Moon or the Sun as the case may be, is influenced by the parallax. These corrections are termed *valana,* which are calculated separately for the first and last contacts.

While discussing the possibility of eclipses it specifies a difference of 13° as the limit in the Kannaḍa version. Then it states "… a little more or less …" would also be allowed. However, the Sanskrit verse has another word '*kiyat*', meaning 11°, which is nott in the translation. All the *siddhāntas* state 13° as the limit for lunar eclipses and 11° for solar eclipses. For instance, the *Sūryasiddhānta* says 11° (Chapter 4.6); Bhāskara II (1114 CE), 14° (*Siddhāntaśiromaṇi*, 4.2); Parameśvara Daivajña (1410 CE), 13° for a lunar eclipse and 11° for a solar eclipse (*Grahaṇamaṇḍana,* 30, 31a); Kamalākara Bhaṭṭa (1658 CE), 14° (*Siddhāntatattvaviveka*); and Bapu Veṅkaṭeśa Ketkar (1916 CE), 13° (*Ketakīgrahagaṇita*, 5.1). The other book, the *Ganitagannaḍi* by the same authors, gives the value as 13°.

The last line of verse no. 4 in the 4th chapter (*Somagrahaṇam*) reads

ग्राह्यौ चन्द्ररवी तयोरवनिभाचन्द्रौ क्रमाद्
ग्राहकौ ॥4॥
grāhyau candraravī
tayoravanibhācandrau kramād
grāhakau ॥4॥

ಚಂದ್ರಾರ್ಕರಿಬ್ಬರೂ ಗ್ರಾಹ್ಯರು |
ಅವರಿಬ್ಬರಿಗೆ ಕ್ರಮದಿಂದ ಭೂಛಾಯೆಯೂ
ಚಂದ್ರನೂ ಗ್ರಾಹಕರು | ಗ್ರಾಹ್ಯನೆಂದರೆ
ಗ್ರಹಿಸಲು ಯೋಗ್ಯವಾದಾತನು |
ಗ್ರಾಹಕನೆಂದರೆ ಗ್ರಹಿಸುವಂಥಾ ಆತನು || 4
||
caṃdrārkaribbarū grāhyaru |
avaribbarige kramadiṃda bhūchāyyū
caṃdranū grāhakaru | grāhyaneṃdare
grahisalu yogyavādātanu |
grāhakaneṃdare grahisuvaṃthā ātanu
॥ 4 ॥

Translation:
Candra is eclipsed by the shadow of the Earth, and *Arka* – *Sūrya* is eclipsed by the Moon.

ग्रह (*graha*) in Sanskrit also means 'toeclipse', hence the word ग्रहणम् (*grahaṇam*). *Candra* and *Sūrya* are *grāhya*s, the ones to be eclipsed, and the shadow of the Earth and the Moon are the *grāhaka*s, the ones that will eclipse them respectively.

The fifth chapter describes the procedure for solar eclipses in 9 verses. Emphasis is on the method of iteration for the calculation for the instants of First and Last Contacts. The lunar eclipse chapter describes the procedure for totality. In the context of a solar eclipse, it states that such a calculation is not needed. There seems to be some error because it declares there is no total eclipse of the Sun. It may be for that year of calculations. From the *Five Millenium Catalog of Eclipses*, we notice that between 1585 and 1604 and again, between 1605 to 1615, there were no total eclipses visible from South India. The one on 29 April 1604 was total for the very southern tip of India, in Kanyakumari. Perhaps this statement was written contextually for that period with no total eclipse visible there.

The sixth chapter with only 5 verses is somewhat unusual. It is for finding the cardinal directions, which is very important in fixing the position angles for eclipses. It explains the practical method to find the East–West line using a gnomon and marking shadows of equal length on either side of meridian. To get the equinoctial shadow (which is extensively used in the calculations), it is suggested that the shadows are measured on both equinox dates and the mean value can be used.

The seventh chapter is on the preparation of a pictorial representation of the eclipse with minute details in 21 verses. It concludes with the procedure for finding the amount of obscuration at a given instant or finding the time for a given magnitude of obscuration.

Figure 3, which we prepared as per the procedure, demonstrates that it is indeed a mirror image of how the eclipse appears in the sky, because of the east–west reversal.

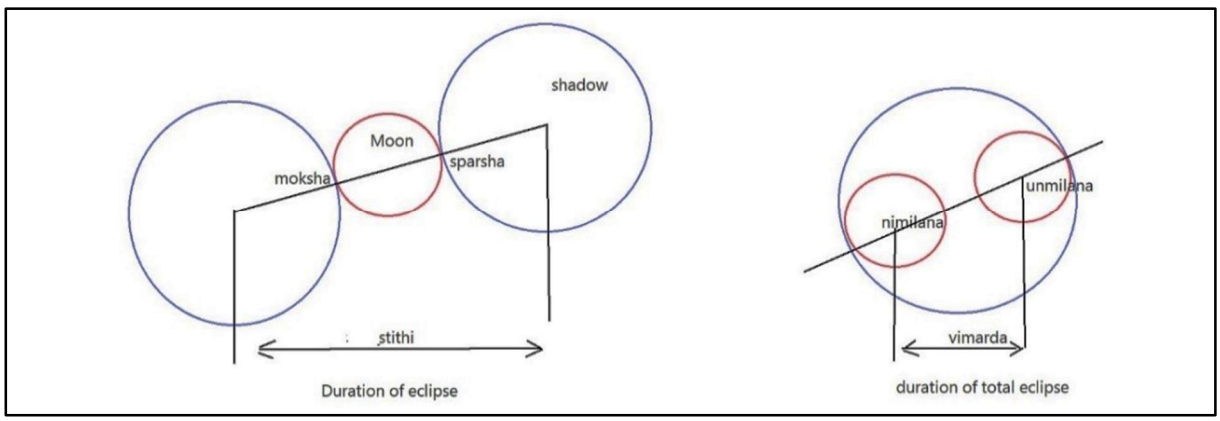

Figure 3: Sample of the depiction of lunar eclipse prepared as per the procedure described in the text (diagram: the authors).

4 UNIQUENESS OF THE TEXT

The texts devoted to only eclipse computations were prepared probably after the fourteenth century. The *Grahaṇārkajñāna* of Brahmagupta and the *Dhīkoṭida-karaṇa* of Srīpati (Pingree, 1994) may be considered as the earliest. These texts are not available now. The other texts are listed in Table 1.

In the *Grahaṇamukura,* the entire text is bilingual; however, the Kannaḍa version is not exactly a translation but some additional explanations are provided. For example, in the context of calculation of the number of revolutions of the Sun the Sanskrit version simply states 'divide by 8926' – the Kannaḍa commentary states that by this procedure (of dividing by 8926) the error incurred is 1 *lipti* (a time unit equivalent to fraction of a second) in 8926 years.

The author also gives the small corrections for the mean values to tally with the *Sūrya Siddhānta* and the *Āryabhaṭa Siddhānta.*

The text is exclusively prescribed for use at Sringeri. The latitude corrections and the monthly corrections for the durations of the day are all listed for this town. It provides a method for getting the equinoctial shadow length (*palabhā*) which is defined as the mid-day shadow of the 12-*aṅgula śaṅku* (12-inch gnomon) on equinoctial days; the procedure is slightly different from the traditional methods, described in texts such as the *Sūryasiddhānta* (Bapudeva Shastry, 1896), and the *Karaṇakutūhala* (Balachandra Rao and Uma, 2008). The equinoctial shadow, *palabhā*, is defined as half of the sum of shadows on both equinoctial meridian transits. This method had been proposed by a few earlier astronomers, such as Lalla, Śrīpati and Āryabhaṭa II. The aim is to achieve accuracy, since the instant of *viṣuvat saṅkrānti* (equinox) need not coincide with the noon on either of the two equinoxes, although this reason is not explicitly stated. However, it can be demonstrated that the result can be improved by choosing that measurement in which *saṅkrānti* occurs closer to or at noon transit than by taking the average of the two measurements.

While describing the central meridian, the name of Karṇāṭa Deśa (the state of Karnataka today) is mentioned. The names Kanyākumārī, Kāñcī, Rauhītaka, Ujjayinī, Kurukṣetra and Mānasa Sarovara are easily identifiable. Some of the other names are not in use today:

> The central [reference meridian] line passes through *laṅkā, kanyākumārī, kāñcī, karṇāṭa deśa, śvetādri, svāmi male, sagarapurī, śrivatsapuri, māhiṣmatī, rauhītaka, ujjayinī, kurukṣetra, himavatparvata, mānasa sarovara and Merugiri.*

An interesting feature of the *Grahaṇamukura* is that it employs some rare meters in the composition of verses, as in the three following examples.

(1) मेघविस्फूर्जितम् (*Meghavisphūrjitam*) (19 syllables). The following example is from Chapter 3.

खसूर्यास्तर्काङ्काः खजलनिधयः स्वाक्षभाघ्नाः क्रमात्ते
चराणां प्राणाः सायनलवरवेर्दोर्गृहाणां गुणाः स्युः ।
युताश्चोनाः प्राणैः खखगजदिशो भांशकाप्ताः प्रमाणे
द्युरात्र्योः सौम्ये स्तः सवितरि गते याम्यगोलेऽन्यथा ते ।। 3.4 ।।

khasūryāstarkāṅkāḥ khajalanidhayaḥ svākṣabhāghnāḥ kramātte
carāṇāṃ prāṇāḥ sāyanalavaraverdorgṛhāṇāṃ guṇāḥ syuḥ।
yutāśconāḥ prāṇaiḥ khakhagajadiśo bhāṃśakāptāḥ pramāṇe
dyurātryoḥ saumye staḥ savitari gate yāmyagole'nyathā te ।। 3.4 ।।

(2) मत्तेभविक्रीडितम् (*Mattebhavikrīditam*) (20 letters)

This is rarely used in Sanskrit, although classical *Chandas* texts have defined it, but it is extensively found in South Indian texts in the Kannaḍa and Telugu languages. The following example is from Chapter 5.

अधिकाल्पे ग्रहणादिमोक्षहरिजे प्राङ्मे भवेतां च ते-
प्यपराह्णे स्फुटपर्वकालहरिजादल्पाधिके स्तस्तदा ।
सहितं तद्विवरेण तत्स्थितिदलं वैपर्यये सन्ध्ययो
रहितं भिन्नकपालयोर्दिनदले तद्योगयुक्तं स्फुटम् ।। 5.6 ।।

Table 1: Indian texts dedicated to the computation of eclipses.

Text	Author	Time
Grahaṇamaṇḍana	Parameśvara Daivajña	1411 CE
Grahaṇavyākhyādīpikā	Parameśvara Daivajña	Fifteenth Century
Grahaṇanirṇayaḥ	Nīlakaṇṭha Somayājī	Fifteenth Century
Uparāgakriyākramaḥ	Acyuta Piśāraṭī	1593
Uparāgaviṃśatiḥ	Acyuta Piśāraṭī	Sixteenth Century
Grahaṇamālā	Hemāṅgada Thakkura	Sixteenth Century
Grahaṇadarpaṇa	Cadurangaraje Urs	Nineteenth century

Figure 4: Seetharama Javagal with the manuscripts (photograph courtesy: Seetharama Javagal).

adhikālpe grahaṇādimokṣaharije prāhṇe
bhavetāṃ ca te-pyaparāhṇe
sphuṭaparvakālaharijādalpādhike
stastadā ।
sahitaṃ tadvivareṇa tatsthitidalaṃ
vaiparyaye sandhyayo
rahitaṃ bhinnakapālayordinadale
tadyogayuktaṃ sphuṭam ।। 5.6 ।।

(3) महास्रग्धरा (*Mahāsragdharā*) (22 letters as against 21 in *sragdharā*). This is not mentioned in the major texts on Sanskrit *Chandas*. *Mahāsragdharā* also has been extensively employed by Kannaḍa and Telugu poets. For instance, *raseyiṃ kālāg-nirudraṃ* in Gadāyuddha (7.15) by the famous poet Ranna. The meter is found in some stone inscriptions in the Kannaḍa region under Vijayanagar empire as well. The following example is from Chapter 7.

शशिनः स्पर्शे च बाहुः स्ववलनसरणौ प्राचि मोक्षे च पश्चात्
तरणेर्व्यस्तः स केन्द्रात् स्वदिशि दिनमणेः स्याद् भुजाग्राच्च कोटिः ।
हिमगोर्व्यस्ता च केन्द्राच्छ्रुतिरनृजुगता श्रोत्रकोट्यग्रयोगात्
क्रमशो ग्रासादिसिद्ध्यै वलयमिह लिखेद् ग्राहकार्धेन धीमान् ।। 7.19 ।।

śaśinaḥ sparśe ca bāhuḥ
svavalanasaraṇau prāci mokṣe ca paścāt
taraṇervyastaḥ sa kendrāt svadiśi
dinamaṇeḥ syād bhujāgrācca koṭiḥ ।
himagorvyastā ca kendrācchrutiranṛjugatā
śrotrakoṭyagrayogāt
kramaśo grāsādisiddhyai valayamiha
likhed grāhakārdhena dhīmān ।। 7.19 ।।

Mattebhavikrīḍita and *Mahāsragdharā* are the most popular meters in this region, and both have been included in *khyātakarṇāṭa vṛttā*s, the six meters that are the celebrated ones in Karṇāṭa deśa. This element also shows that the present work was composed in the Kannada–Telugu dominating region.

It is planned to publish the entire text in its original format with an English translation and explanatory notes.

5 CONCLUSIONS

We have presented a rare sixteenth century Kannaḍa manuscript that describes the method of calculating eclipses. It was mentioned in the catalogue by Pingree (1944) and without access to the manuscript itself was attributed to Viddaṇācārya. The only available copy of the manuscript was with the family of a famous father–son duo of astronomers. On the basis of the language and date of the manuscript we deduce that this work also is authored by one of them. We have presented the salient points in the text, which has the procedure for depiction of eclipses by drawings.

6 NOTES

1. Seetharama Javagal (1947–2023; Figure 4), grandson of Kulapati Śaṅkaranārāyaṇa Joyisaru did the entire work of reading, editing and conversion of the unknown script to computer-readable format with great care. He was very keen on publishing this manuscript along the same lines as used for the *Gaṇitagannaḍi* and the *Karaṇābharaṇam*, but unfortunately did not live to see the final version.

7 ACKNOWLEDGEMENTS:

We dedicate this paper to Seetharama Javagal who was instrumental in bringing to light this rare manuscript. We are thankful to Dr B S Shubha and Vinay Iyer for helping in the preparation of the manuscript. One of the authors (RP) acknowledges the IKS Division, Ministry of Education, Government of India for the financial support and encouragement to carry out this research work.

8 REFERENCES

Balachandra Rao, S., and Uma, S.K., 2008. *Karaṇakutūhalam of Bhaskaracarya II, With English Translation, Notes and Appendices.* New Delhi, Indian National Science Academy.

Bapu Deva Sastri, 1861. *Translation of the Sūryasiddhānta*. Calcutta, Google Books (https://www.wilbourhall.org/pdfs/Translation_of_the_S__rya_siddh__nta_by_.pdf).

Chatterjee, B., 1981. *Śiṣyadhīvṛddhida tantra of Lalla with the commentary of Mallikārjuna Sūri; critical edition with introduction, English translation, mathematical notes, and indices*. New Delhi, Indian National Science Academy.
Dikshit, S.B., 1896. *Bharatiya Jyotihssatra* (in Marathi). Poona; reprinted, Poona 1931; English translation by R.V. Vaidya, English Translation of Bharatiya Jyotish Sastra (History of Indian Astronomy), Part I: History of Astronomy during the Vedic and Vedanga Periods, Delhi 1969; Part II: History of Astronomy during the Siddhantic and Modern Periods, Delhi 1981 (https://jyotishbooks.wordpress.com/2020/09/30/bharatiya-jyotish-sastra-vol-2-by-shankar-balakrishna-dikshit/).
Mahesh, K., and Javagal, S., 2020. *Karaṇābharaṇam, A commentary on Karaṇaprakāśa of Brahmadeva by Śaṅkaranārāyaṇa, the Son of Śṛṅgapurī Dēmaṇa Joyisa.* Tirupati, Rashtriya Sanskrit Vidyapeetha.
Pingree, D., 1994. *A Census of the Exact Sciences in Sanskrit*. Philadelphia, American Philosophical Society (Series A, Volume 5) (https://ia600809.us.archive.org/32/items/PingreeCESS/Pingree_CESS_A5_1994.pdf).
Shylaja, B.S., and Javagal, S., 2021. *Ganitagannaḍi – An Astronomy Text of 1604 CE by Shankaranarayana Joyisaru of Sringer*i. Bengaluru, Navakarnataka Publications.
Web source: https://eclipse.gsfc.nasa.gov/SEcat5/catalog.html

Dr. B.S.Shylaja hails from Bengaluru. After completing an MSc in Physics at Bangalore University, she had a brief tenure at the National Aerospace Laboratories and the Central Power Research Institute before joining the Indian Institute of Astrophysics. There she studied binary stars with Wolf–Rayet companions for her PhD thesis (1987) under the guidance of the late Professor M.K.V. Bappu.

Shylaja also studied comets (including 1P/Halley), metallic line stars and cataclysmic variables (CVs). The rapid oscillations of the CVs were recorded with a fast photometer that was designed to record lunar occultations. She also studied the signatures of winds of the massive stars in the infra-red while at the Physical Research Laboratory in Ahmedabad.

After joining the Jawaharlal Nehru Planetarium in Bengaluru in 1994 she began studying historical aspects of Indian astronomy. She translated into English the monograph about the 1874 transit of Venus written by Chintamani Ragoonatha Charry in Kannada, a language of South India; this throws light on the techniques used by the Indian astronomers of that era. She has also written many books in Kannada and in English. These include books on the transit of Venus and a book on understanding Jantar Mantar, with pop up pages. She has studied the temples of India for their astronomical significance.

Shylaja has found a new source of astronomical records—stone inscriptions—all over India and South Asia. Her book *History of the Sky – On Stones* (2016) is a compilation of the eclipse and planetary conjunctions cited in these inscriptions. They have been found very useful in that they extend back more than 1500 years. She has also published a translation, with commentary, of the seventeenth century manuscript *Gaṇitagannaḍi: Mirror of Mathematics* (2020, co-authored by Seetharama Javagal).

As a former observational astrophysicist Shylaja also has studied the records of observations of stars from various texts and from the traditions of the navigators, with the aim of deducing the earlier observational techniques that were prevalent in India.

Dr. Ramakrishna Pejathaya is an Associate Professor in the Centre for Indian Knowledge Systems at Chanakya University in Bengaluru. After completing his Master's in *Jyotiḥśāstra* (traditional Indian Astronomy and Astrology) from SMSP Sanskrit College Udupi, Pejathaya carried out his doctoral study on the *Siddhāntaśekhara* (twelfth century treatise on astronomy) of *Śrīpati* and its influence on later astronomers, under the guidance of Professor A. Sripada Bhat from the National Sanskrit University in Tirupati.

Dr. Ramakrishna has been actively involved in teaching and research in the areas of *Jyotiṣa* (traditional Indian astronomy), Sanskrit literature and poetics for the last 15 years. He has several research projects, papers and books to his credit. Noteworthy of them isthe encyclopedia project titled *Jyotiṣaviśvakoṣa* for which he worked as a co-investigator from 2014 to 2019. The output of this project has been published in nine volumes by the SMSP Research Centre in Udupi.

As an accomplished *Aṣṭāvadhāni*, Dr. Pejathaya has performed and popularised the art of *Avadhāna* in different parts of Bharata(India). *Avadhāna* is a classical intellectual art form of India, which involves the extempore creation of metrical verses on a variety of topics under myriad aesthetic constraints. This unique art form requires expertise in multiple branches of knowledge as well as immense memory power. It also showcases various cognitive abilities such as multitasking and lateral thinking since the performer is expected to address multiple tasks simultaneously.

Seetharama Javagal (1947–2023; see Figure 4 above) started his career as an electrical engineer. He investigated his family roots, and his inquisitiveness led him to a deeper understanding of 'Jyotisha', as an authentic science of astronomy and mathematics. He resolved to preserve his family's heritage, bringing forth his ancestors' scholarly works and the 'Granthas' written by them as palm leaf manuscripts, and to make these readable for future generations.

At the age of 63 he studied for an MA in Sanskrit and graduated with distinction from Karnataka State Open University (Year 2011). He travelled the length and breadth of the country, discussing with scholars and visiting

many libraries, universities and research institutions to learn about manuscripts, confirm their origins, compare them with other works/sources, and authenticate them. He undertook the preservation of the available palm-leaf manuscripts from INTACH in Bengaluru. Many of the palm-leaf manuscripts were in the 'Nandinagari' script. With great effort and dedication Seetharama learnt the Nandinagari script, and he successfully started transliteration of the contents of the palm-leaf manuscripts to regular Unicode script.