A UNIQUE APPLICATION OF THE OBSERVATION OF STARS IN INDIAN ASTRONOMICAL TEXTS

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Abstract: It is very well known that the observation of stars constituted an integral part of Indian astronomical texts. The twenty seven stars along the zodiac were used as references for longitudes. Here we discuss an application which is generally not highlighted. The method uses the meridian transit observation of stars to determine the ascendant (*lagna*), as cited in the seventeenth-century manuscript *Brahmatulya Udāharaṇam* by Viśvanātha. We assess the method of calculation and discuss the possibility of a table being prepared based on observations.

Keywords: observational astronomy; Medieval manuscripts; *lagna* (ascendant); meridian transits of stars; *Brahmatulya Udāharaṇam*.

1 INTRODUCTION

The study of astronomy with deep roots dating back to thousands of years has influenced the traditions. The versatility of the observational aspects, however, are yet to be established. This is partly because the details on observational procedures, corrections and errors have not been discussed in detail in many of the texts. Some of the manuscripts available provide ample opportunities for studying the concealed finer details on observational procedures. *Brahmatulya Udāharaṇam* from the seventeenth century is one such manuscript. It has various examples for different celestial phenomena involving basic observational concepts of astronomy. We present here a very brief mention of a technique cited in this manuscript for fixing the *lagna* (the ascendant, orient ecliptic point) by observing the meridian transits of any one of the twenty-seven stars, called the *yogatarās* of the *nakṣatra* system. This provides clues on practical modes of observation and the identification of the stars.

A large number of manuscripts pertaining to Indian astronomy have been rendered user friendly—thanks to the efforts of many scholars in the last few decades. Most of them are text books explaining the basic concepts and theory (*siddhānta*). Practical aspects such as measuring the positions and deriving the orbits are not explicitly written down. Further, the associated mathematical formulae are assumed to be familiar to the reader. Thus, we have a genuine problem in understanding the practical methods employed by these astronomers.

2 THE IMPORTANCE OF THE MANUSCRIPT

The medieval period saw many Indian scholars engaged in the preparation of tables and simplified procedures in texts classified as *sāriṇī* and *udāharaṇam*. Here some hints relevant to details on observational astronomy are concealed. Generally, any astronomical text discusses the astronomical events like eclipses, in great detail; conjunction of planets and stars, retrograde motion and many more events are also included. The texts labeled as *udāharaṇam* demonstrate the application of the theoretical procedures for practical use and hence serve as handy manuals.

The study of manuscripts of the medieval period in depth, focuses into the development of observational astronomy in India. Here we have chosen *Brahmatulya Udāharaṇam*, (BU, hereafter) one such manuscript based on Karaṇakutūhala of Bhāskarāchārya II. Two copies of manuscript, A and B, were found in Bhandarkar Oriental research Institute, Pune, and edited (Shubha, 2020; 2023; Shubha and Shylaja, 2023; Shubha et. al., 2020). This seventeenth century paper manuscript gives adequate number of solved examples on various events like eclipses, conjunctions, retrograde motion and moon's cusps.

We are describing here the details from the chapter on conjunctions pertaining to stars. The conjunctions can be among planets, and also among planets and stars. The basic requirement is the knowledge on the position and rate of motion of the two bodies involved for a given date. The instant of conjunction is calculated by

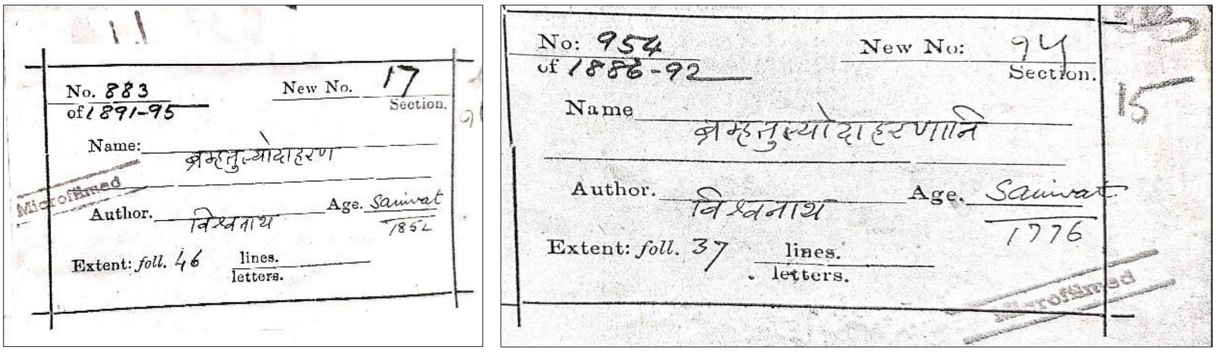

Figure 1: The cover pages of the manuscripts A (no.883) and B (no.954).

method of iteration and difference in rates of motion is used for this computation. However, if one them is a star, the position of the planet on a given date and its rate of motion would suffice.

3 ABOUT THE AUTHOR AND THE STAR LIST

Vishvanatha Daivajña is a very well-known name among the astronomers of seventeenth century. His commentaries and worked examples are extensively cited and studied. As mentioned in the colophon, his father was Divakara Daivajña of Golagrama. His commentaries are rich in explanation and the examples extend to all types of celestial phenomena. This text BU, is dated *Saka* 1557 (CE 1635) with examples of contemporary events for Vārāṇasi (25° 34′ N). His other works include commentaries on various treatises, for example, *Gahanārtha prakāśikā,Siddhānta-Siromani, Karaṇakutūhala, Makaranda Sārini and Pāta Sārini* (Dikshit, 1978). Since BU, as suggested by the title, is a text devoted to solved examples, the theoretical background on the part of reader is assumed.

The discussion of *Aśvinyādi* stars (starting from *Aśvini,* called *yogatāras*, or junction stars) is generally found in all treatises under the chapter on conjunctions usually titled *grahayutyadhikāra*. The coordinates of the stars are drawn from the *Sūryasiddhānta* (SS, hereafter) or some other standard text, such as the *Karaṇakutūhalam*. The procedure to calculate the conjunction with stars is explained.

BU differs from other Indian texts in this procedure. It does not provide the coordinates of the stars directly. The chapter opens with this remark:

> अत्राचार्येण अश्विन्यादि नक्षत्राणां 'उदयमध्यास्त लग्नानितोक्तानि' अतो मकरंदस्य लग्नानि श्रीमद्विष्णुदैवज्ञैरेकादशभिः श्लोकैः बद्धानि । तानि प्रसंगादत्र लिख्यन्ते ।
>
> atrācāryeṇa aśvinyādi nakṣatrāṇāṃ 'udayamadhyāsta lagnānitoktāni' ato makaraṃdasya lagnāni śrīmadviṣṇudaivajñairekādaśabhiḥ ślokaiḥ baddhāni | tāni prasaṃgādatra likhyante |
>
> The *lagnas* of the stars starting from *Aśvinī* in the context of rise, meridian transit and set as told by Makaranda and composed by Ācārya Viśṇu Daivajña into eleven verses are written down, for the need here.

Here we had difficulty in reading *lagnānitoktāni*; the words shown in quotes was not there in the second manuscript. Therefore, we could not cross check for any spelling mistakes. We have read the letter as '*to*' in between '*lagnānī*' and '*ktānī*'.

The term *Aśvinyādi* refers to twenty-seven stars that are used for fixing the day of the month, *tithi*, with reference to the conjunction with the Moon. Generally, we see a list of the coordinates which are more or less identical in all the texts. From the above statement, it is clear that the verses were composed by Ācārya Viśṇu Daivajña, based on the proposition by Makaranda for the purpose of *lagna*. Makaranda (Uma et al., 2018) is the name of the astronomer well known for preparation of tables bearing his name; they were very popular all over India. The other name, Ācārya Viśṇu Daivajña, has not been mentioned in any other text known to us, so his works are yet to be discovered. Furthermore, it is stated (रात्रौ खमध्यस्य नक्षत्रावलोकनादेव – rātrau khamadhyasya nakṣtrāvalokanādeva) that the objective is to get the *lagna* by (only) merely observing the meridian transit of stars in the night.

Our study concentrates on this passage pertaining to the description or finding the *lagna* (*ascendant*) during the night by observing the stars. The numbers are listed as tables inserted in between the running text as shown in Figure 2 from Manuscript A.

The tables run in to three rows, the top row refers to the first syllable of the name of the star,

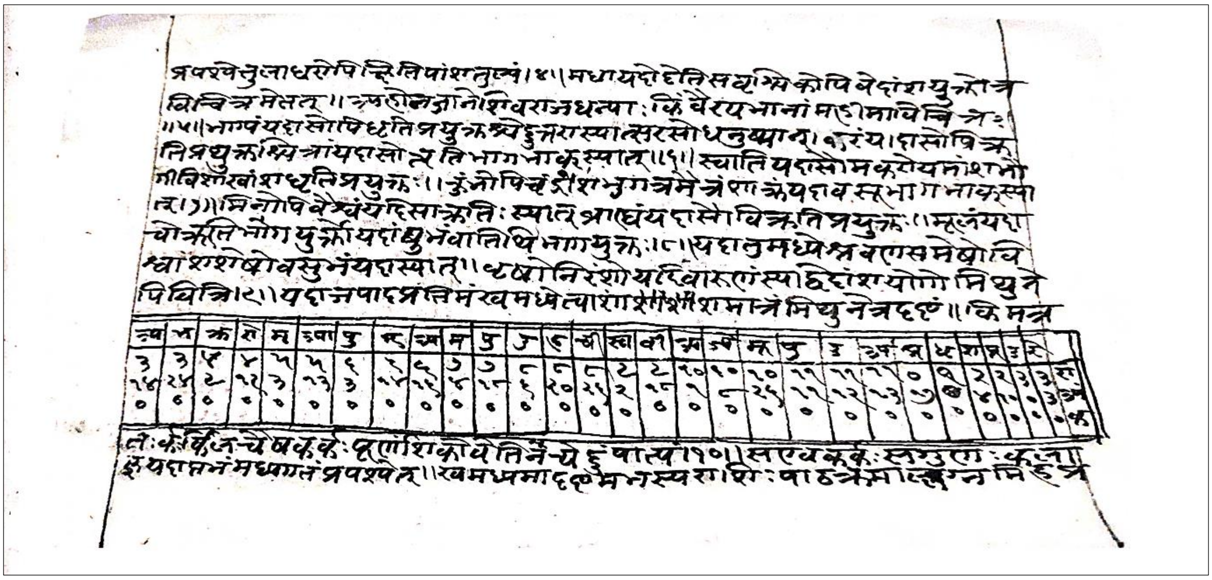

Figure 2: The listing of the longitudes in the manuscript. The top row is the name of the star (first syllable); second row, the number to be multiplied by 30, written as *rāśi*. The third row is ° and the fourth, minutes, which is zero for all. Verses 4 to 10 (actually 3 to 9, see Appendix) are also readable above the table.

Table 1: The longitudes (of *lagna*) when the relevant star is on the meridian as listed in the text.

Name	Longitude (°)	Name	Longitude (°)
Aśvinī	104	*Svātī*	270
Bharaṇī	114	*Viśākhā*	288
Kṛttikā	129	*Anurādhā*	301
Rohiṇī	141	*Jyeṣṭa*	308
Mṛgaśirā	152	*Mūlā*	326
Ārdrā	163	*Pūrvaṣādhā*	335
Punarvasu	183	*Uttarāṣādhā*	342
Puṣyā	194	*Abhijit*	353
Āśleṣā	196	*Śravaṇa*	17(17+360)
Maghā	214	*Dhaniṣṭhā*	30(30+360)
Pūrvāphālguṇī	228	*Śatabiṣā*	64(64+360)
Uttarāphālguṇī	246	*Pūrvābhādrā*	62(70+360
Hastā	260	*Uttarābhādrā*	80(90+360)
Cittā	266	*Revatī*	93(93+360)

star, the second, the multiplier or the number of previous *rāśi* (1 *rāśi* = 30°) as a unit of 30° and the third, the ascendant in°. For example, *Aśvini* is given as 3 in the top row, and 14 in the second row. It implies *3 rāśis* are elapsed and 14°, i.e., 90+14=104 °. These values are listed in Table 1 and plotted in Figure 3. The decoding of the verses with *bhuta saṅkhyā* system of numerals was not easy, because there was a mismatch between the two manuscripts due to some missing phrases. We have provided the verses and our interpretation in the Appendix. We note that the names of the zodiacal signs have been correlated directly with different numerals, so that *meṣa* is 30°, *vṛṣa* is 60° and so on. For example, the phrase *meṣo viśvāṃśa-śeṣa* is used for number 17. This means the remainder of subtracting 13° (*viśvāṃśa*), from *meṣa,* i.e. 30°. We also found that the sequence can be maintained by swapping the lines in verse number 7.

All the numbers were cross verified with the second manuscript; the entry for *Uttarābhādra* is 2|10 as can be read in Figure 2. However, it is 2|20, as per the second manuscript.

4 *LAGNA*, THE ASCENDANT

Lagna is a general term used to represent the zodiacal sign *rāśi* when rising (*udayalagna*), setting (*astalagna*) or transiting the meridian (*madhyalagna*). However, when only *rāśi* is mentioned, it is understood as that constellation of the zodiac, which is rising at the desired instant. It serves as a measure of the time of the day when the position of the Sun is known. The procedure for calculation is generally described in all introductory texts (Balachandra Rao and Uma, 2008; Subbarayappa and Sarma, 1985), extensive treatises and commentaries (Arkasomayaji, 1980; Chatterji, 1981; Ramasubramanian and Shylaja and Punith, 2024; Sriram, 2011) and manuals or *karaṇa* texts (Mahesh

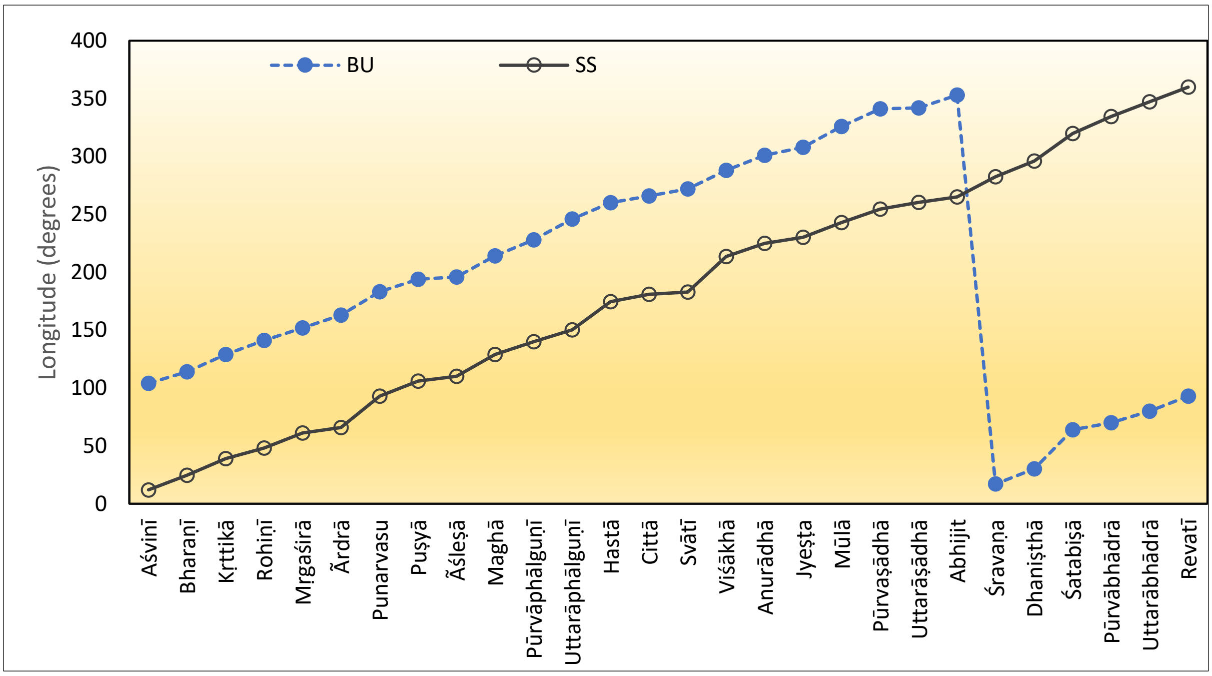

Figure 3: Longitudes of the *lagna* in BU corresponding to the longitudes of the junction stars (*yogatāra*) from SS. The sudden jump (360+) in the values of BU for the last six points is because of the apparent difference of about 90°.

and Seetharama, 2020; Shylaja and Seetharama, 2020; Shylaja et. al., 2024; Venketeswara Pai., et al., 2018) and many more. For traditional purposes it is limited to the name of the zodiacal constellation, which serves as a time reference within the interval of 2 *ghaṭi* or less. This procedure of naming the ascendant to mark the time of the event has been in practice for all traditional and religious events even today. The duration needed for the rise of the 30° is also specified. For example, *meṣa lagna* implies that Aries is on the Eastern horizon (for 248 *vināḍis*), *vṛṣabha lagna* implies that Taurus is on the horizon (for 275 *vināḍis*). Although, they correspond to intervals of 30°, the duration varies with tlatitude. It is convention to express *lagna* in time units *ghaṭi* / *vighaṭi*, which has some advantages for calculating the time of the event with reference to sunrise or sunset.

For the purpose of fixing the onset of events like eclipses a similar notation may be used. However, it demands greater accuracy, which is provided by the actual longitude of the ascendant. Therefore, the task is to fix the point on the ecliptic which is on the Eastern horizon at the desired instant. The conventional method of specifying only the name of the constellation, which provides an interval or subdivisions of 30° or about two *ghaṭi*s, proves inadequate (thus, the duration of *lagna* can stretch up to more than an hour).

The verses provide numerals for the *lagna* for a given star in *bhūtasaṅkhyā* system, which puts the numbers in terms of objects (for example, the word *netra*, the eye, means 2). These were used only for cross verification. For example, for the star *Pūrvāaṣāḍha*, the table lists 16 while the verse states *tithi*, which means 15. The *lagna* as listed in the verses is in units of *rāśi* and *aṁśa* are tabulated in *aṁśa* (°) (1 *rāśi* = 30°) and we have written in units of ° in Table 1.

BU does not state anything explicitly on the method or derivation to get the *lagna* which is implied here. To establish the type of *lagna*, we take the longitudes of stars from SS (Saha, 1955) which have been plotted in the same graph (Figure 1). Indian texts such as SS provide *dhruvaka* and *viksepa* which have to be converted to conventional coordinates (Venketeswara Pai and Shylaja, 2016). Here the converted coordinates are used. The systematic difference of 90° implies that the numbers refer only to *udayalagna*, although the opening statement (cited above) in the commentary mentions all the three *lagnas*.

As we explain now, BU provides an alternate and more accurate method of finding *lagna*, the ascendant (preliminary results in Shylaja and Shubha, 2023). The foremost requirement for understanding these methods used in Indian astronomical text is the coordinate system itself (Shylaja and Pai, 2018) by providing the longitude of the point on the ecliptic (*lagna*) corresponding to the meridian transit of the star. A quick glance reveals the improvement on accuracy since the interval between the meridian passage of stars approximately corresponds to less than an hour (the passage of 27 stars over 24 hours). This method is particularly useful when the Eastern horizon is not visible for any reason; and the meridian is visible. Observing a star when it transits the meridian is definitely preferable to observing it near the horizon.

5 DISCUSSION

Let us study the first verse to decode the values. The first phrase states 'when one sees the star *Aśvinī* on the meridian, 14° in *Karka*' is rising. *Aśvinī* has another name *Dasram*, which is used here. 14 is indicated by the word *śakrāṃśam.* Here it is presumed that the user is aware of the addition of 90°:

dasraṃkhamadhyepravilokayetyaḥ
karketi śakrāṃśasamobhyudeti |
sa eva yāmyaṃ yadi siddhatulyaḥ
siṃhognibhaṃ tat khacarāṃśa eva || *1* ||

When *dasram*, (*Aśvinī,* β Ari) is on the meridian, the longitude tabulated is 104°, which is simply 90°+14. Here, 14° (*śakrāṃśa)* is the numeral corresponding to *Aśvinī*. The next star *Bharaṇi* (41 Ari) is assigned 24° (*siddhatulyaḥ)* and the corresponding entry is 90° + 24°. Thus, it appears as though the quick guess of adding 90 would suffice to get the *lagna*. The next one for *Kṛittikā* (called *Agni*), is given by the phrase, (*khacarāṃśa*), meaning the number of movable ones or *grahas* in sky), implying 9° in Leo (*Simha*).

Similarly, we have decoded and cross verified all the numerals for the stars, tabulated in Table 1 and plotted in Figure 3 with longitudes from the SS. It is obvious in Figure 3 that there are small deviations in the apparent parallel curves. However, as we see now, these two examples of *Aśvinī* and *Bharaṇi* appear to be exceptions. The procedure is not so straight forward for other stars.

Let us consider a star X whose coordinates are marked in Figures 4 and 5. Its hour circle meets the ecliptic at B. Thus, when the star X is on the meridian, the point A is not on the meridian. Instead, B is on the meridian. Thus for the *lagna* calculations, the reference is the longitude of B. Neither the longitude–latitude system (λ, β) nor the right ascension–decilnation system (α, δ) provides the coordinates of B. We need to calculate it seperately.

As mentioned earlier, *dhruvaka* and *vikṣepa* (γB, BX) have to be converted to conventional coordinates, for comparison with the conventional systems using the standard formulae. As a first step, the *dhruvaka* and *vikṣepa* are converted to λ and β, which, in turn can be converted to α, δ using standard transformations (Saha, 1955), with an intermediate step for calculating the position B. It is easily seen that the difference in longitudes AB is dependent upon XA. The formulae derived are for an approximation when XA is a small angle, which is true for most of the twenty seven stars here.

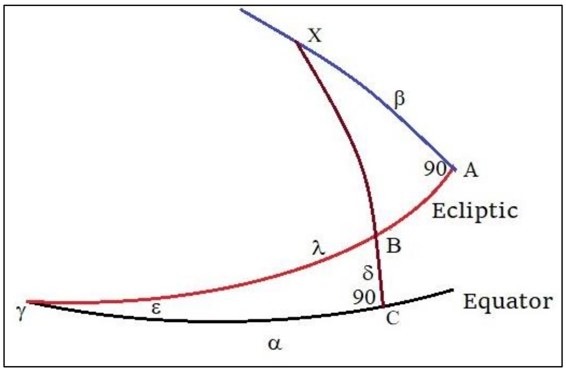

Figure 4: Definition and conversion of coordinates. The point B on the ecliptic is the reference for the calculation of the *lagna*. The longitude is γA or λ and the right ascension α, or γC. The declination is XC or δ and the latitude AX or β.

As the second step we calculated the *lagna* corresponding to point B on the meridian. The conventional methods use the predetermined ready reckoner tables for the latitude of the place. We have attempted the same directly with the angles. Convertion of λ, β to α, δ would give us the α_B of point B (which is same as that for X) as well. Using this α_B, working back with β = 0, we get λ_B of point B. Alternately, we can use the formula,

$$AB = \beta \cot \alpha \sin \delta \quad (1)$$

This implies a direct dependance on β.

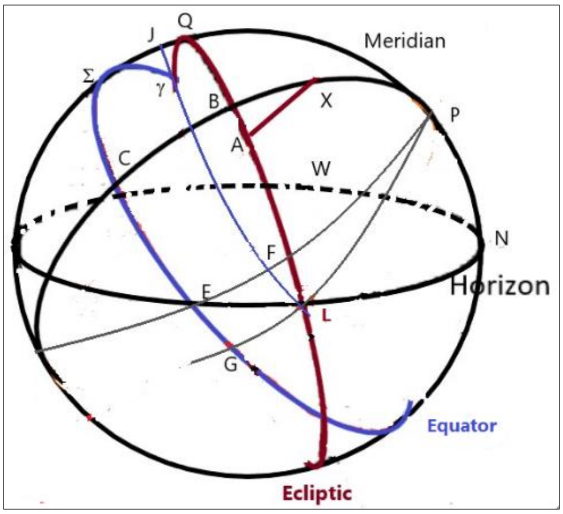

Figure 5: The explanation for the point B which is used for the longitude calculations. γΣCE is the equator; γQBA is the ecliptic; PE Hour circle is also known as 6' O clock circle. PXBC is the hour circle of the star. AX is the latitude along the perpendicular to the ecliptic.

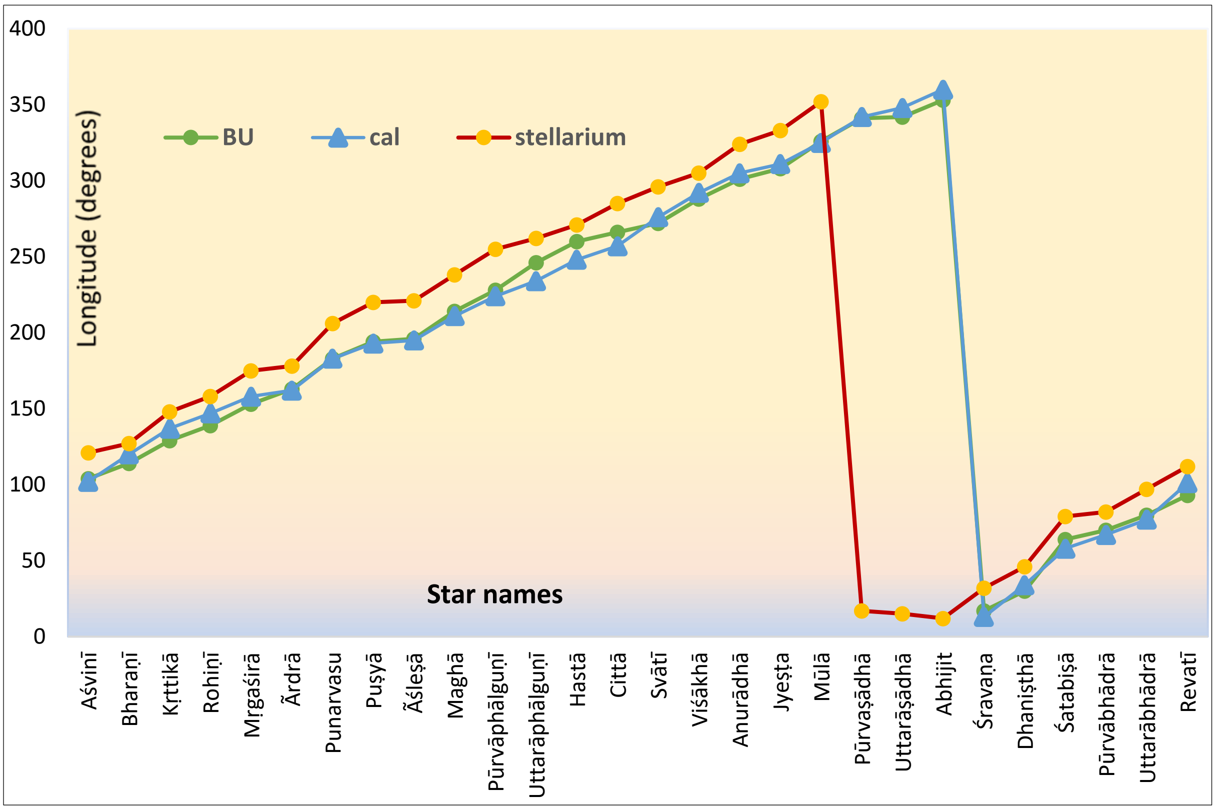

Figure 6: Comparison of the calculated values of the longitudes of the *lagna* with those listed in the manuscript. The readings from Stellarium are for the current year (2024).

As the third step we add 90° to α_B. This takes us to the point on the horizon. We find the longitude λ_L corresponding to the ($\alpha_L = \alpha_B + 90$). Assuming that, this is nearly the longitude of the *lagna* point, i.e, $\lambda_L = \alpha_L$, and we calculate the Declination δ_L as

$$\sin \delta_L = \sin \lambda_L \sin \varepsilon \quad (2)$$

Now, we calculate the hour angle H, (angle JPL) which is added to λ_L to get the longitude of *lagna*

$$\cos H = -\tan \varphi \tan \delta_L \quad (3)$$

where φ is the latitude of the place (Varāṇasi). From the results, we note that the assumption that $\lambda_L = \alpha_L$ is justified.

The twenty-seven stars identified in the sky, referred to as *yogatāra*, lie close to the ecliptic and have small latitude values. Moreover, they are not equally distributed along the ecliptic. The rule is not applicable to the 28th (*Abhijit*), Vega, which is about 60° to the north of ecliptic.

In this method of observing the star to fix the ascendent, observational details or practical details are not explicitly mentioned. The difficulty in the procedure is concealed in Figure 6, which compares the *lagna* calculated by the above method with those in BU. The plot also includes the *lagna* read out from Stellarium. (Zotti et. al., 2020). We chose the year 2024, so that the trend is easily observable, without which, all the points would overlap. The difference between the values calculated by us (λ_{cal}) and those from BU (λ_{BU}) are apparent. The small deviations are within the observational errors and hint at the practical difficulty. In most of the cases, the difference is less than 5°. If the star is not very bright, identifying its meridian transit may be difficult. This explains the larger difference in the cases of *Bharaṇī* (41 Ari), *Mrigaśirā* (λ Ori), *Uttrāṣaḍha* (σ Sgr) and *Revati* (ζ Psc). For *Aśvini* (β Ari) and *Ārdrā* (α Ori), there may be misidentification—*Aśvini* is the second brightest star in Aries and is very close to the brighter star (α Ari). We also note that *Ārdrā*, used to be identified with γ Gem (Shylaja and Pai, 2024), but subsequently got identified with α Ori, somehow. This confusion may have reflected as the error, here. In the case of *Svāti* (α Boo), *Abhijit* (α Lyr) and *Dhaniṣṭhā* (β Del), although the latitude is quite large, the approximation on small value of β in the equations appears to be valid, or we can justify them based on observations. (Shylaja and Pai (2016) have a typographical error for the latitude of *Abhijit* (α Lyr) which has been corrected here.)

Kṛittikā (η Tau)*, Dhaniṣṭhā* and *Hastā* (δ Crv) are bright and the identifications are unambiguous. However, they are star clusters; not single stars but small groups of many stars;

therefore, the choice of a specific star within the cluster may have caused some confusion, while monitoring the meridian transit.

The only assumption we made in the procedure was that the right ascension of *lagna* is the same as its longitude, for the purpose of calculating the corresponding declination. The agreement (within observational errors) of the values leads us to think that this assumption is valid. Now, we ponder about the procedure that might have been adopted for the composition of the verses (and the preparation of the tables). The easiest way would be to note them down by direct observations, because they are latitude specific. That sounds practical also because of the advantages of measuring coordinates of any star on the meridian (as against the coordinates of a point at the horizon, exactly on the ecliptic). This method is likely to reduce the errors especially if the star is faint. On the other hand, the indirect way of calculating *lagna*, as shown above, might not have been very difficult either. There is a third possibility—using a table-top model of the celestial sphere with graduated circles for the equator, ecliptic and meridian. One needs to adjust the horizon for the given latitude. By manually rotating the sphere so that the star transits the meridian, the *lagna* can be read out on the graduated scale. The construction of such spheres, called *gola yantra*, is described in many treatises, for example, the *Siddhānta Śiromaṇi* and the *Śiśyadhivṛddhidatantra*. The last verse states "when *Abhijit* (with latitude of 58°) is on the east, *Mṛgaśira* is on the west", which is true for Vārāṇasi and easily verifiable. This correlates with the possibility that these numbers have been obtained by direct observations.

That leads us to the question of the mode of observation and the type of instrument that might have been used for measuring. It involved simultaneous measurement at the meridian as well as at the horizon in the plane of the ecliptic, although such an instrument is not explicitly discussed anywhere (although the currently defunct instrument called the *Krānti yantra* at Jai Sing's eighteenth-century observatory at Jaipur may have been used for this purpose). The small errors within a few degrees add to the clue that these numbers were arrived at by actual observations. Once the numbers were known, they could be composed as verses and memorized. These verses will be valid for places with the same latitude. Thus, the texts have different verses (formulae) depending on their latitudes.

This method of fixing the *lagna* with the meridian transit of star was well established during the time of Ganeśa Daivajña. It is stated by Dikshit (1978: 359) that

> Once the author happened to meet a Vaidik Brahmaṇa, named Phaphe from Chaul in the Colaba district. He knew all the nakśatra's. He recited a verse showing how to find the length of the night by observing the star transiting the meridian. It is given here because of its much usefulness. When the nakṣatra Aśvini is transiting the meridian, the ascendant at that time is 102 (that is to say 12 of the Cancer have risen at that time). It thus gives ° of the ascendant in the case of 28 nakṣatras. The time should be determined by the useful method finding the (unknown) time when the ascendant is given. This quotation is based on the numerical code of Aryabhata II, in which consonants ka, ta, pa, ya, indicate numerals; but in addition to these vowels also indicate natural numbers …'

The values of the longitudes corresponding to stars are given as Khau 102, Khu 112, Ja, 128, Tri 140, Gu 153, Chu 156, Gai 183, Cho 196, Chho, 197 and so on. These numbers slightly differ from those given in Table 1. This can be attributed to the difference in latitude.

Dikshit (*ibid*.) attributes this method of getting the *lagna* by meridian transit to Ganeśa Daivajña, and cites three reasons:

(1) His work *Muhurtasindhu* has exactly similar verses;
(2) The values agree with a *palabha* (equinoctial shadow) of 4 *aṅgulas* (corresponding to about 18° N); and
(3) It is briefly stated in the *Grahalāghava*.

Although the BU belongs to a date later than Ganeśa Daivajña, its author points out a different source (Viśṇu Daivajña, hitherto unknown) for the verses. Therefore, it appears that the method was well established before the fourteenth century.

There is a very interesting footnote for the above narration. The *Vaidik Brahmaṇa* pointed to a wrong star for *Revatī*. Dikshit (*ibid*.) notes that this error was observed with two more experts from Ratnagiri and Dhulia around the same region. Although this error is judged to have been carried forward from the days of Ganeśa Daivajña, it reflects the idea that the identification may have been a genuine problem.

A recent work on a similar method of reckoning the ascendant (*lagna*) based on verses (transmitted orally) was brought to light by two sources in regional languages. A seventeenth-century palm leaf manuscript in a private collection in Kannaḍa (Devaraja Swamy, 2022) preserved in the small town Keremane, in Karnataka, provides verses for *lagnas* corresponding to the meridian transits of stars in time units. As a small boy Professor Krishnamurthy (2023) had learnt similar verses from his father in Cuddalore, a small town in Tamil Nadu. He has given the details of the Sanskrit and Tamil verses in his book *When Stars Tell Time*. The verses in these two sources appear identical but for minor changes in the fraction of the time units, which may account for latitude corrections.

Thus, we realise that this unique method of utilising the meridian transits of stars to fix the ascendant and get the time of the night was in use until about 80 years ago. We get a hint of this from an unusual source (Narayan, 1955), which is a fiction by this famous novelist; it describes the knowledge of stars in the sky, and ability to tell the time of the night was a mandate. It is quite probable that many nonagenarians like Prof Krishnamurthy recollect these verses, which are specific to a region. Likewise, such formulae may be available in various regional languages, but are on the verge of being lost. The need of the hour is to retrieve and decode them as a testimony of this unique application before they disappear forever.

6 CONCLUDING REMARKS

The manuscript BU provides longitudes of the ascendant, *lagna*, corresponding to the twenty-eight *nakśatras*. This unusual practice of listing longitudes of *lagna*, instead of the coordinates of the stars themselves, was investigated with the purpose of understanding the techniques that were in use during earlier times. These longitudes are expressed in the *bhūtasaṅkhyā* system. We show that they have been corrected for the declinations / latitudes of the stars, which are unequally spaced along the ecliptic path. Conventional methods provide accuracy within 30° for the *lagna.* Owing to this, the duration of the *lagna* approximates to *rāśis*, and extends to an hour and beyond. We show that the small correction for the latitudes of the stars (not on the ecliptic) also have been taken into account, which proves that this is based on observations. This method of observing the meridian transit of a star has practical advantages over observing a star near the horizon. Therefore, this method may have been explored for better accuracy (of a few degrees). The possibility of the table being constructed based on actual observations cannot be ruled out.

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9 APPENDIX

This Appendix reproduces the eleven verses in BU and deciphers the numbers in them; the mismatch in numbering the verses between the two manuscripts has been rectified.

dasraṃ khamadhye pravilokayet yaḥ karoti[1] *śakrāṃśasamobhyudeti* |
sa eva yāmyaṃ yadi siddhatulyaḥ siṃhognibhaṃ tat khacarāṃśa eva || *1* ||
#dasraṃ-Aśvinī, khamadhye -zenith, karketi=Cancer, śakrāṃśa-14, yāmyaṃ-Bharaṇī, siddhatulyaḥ-24, siṃho- Leo, agnibhaṃ- Kṛttikā, khacarāṃśa-9
brāhmabhaṃ[1] *padaṃ cet satato'tivṛtyā kanyāpi tāvanmṛgayenmṛgaṃ cet* |
tannetra sāmyaṃ hi bibharti caivaṃ viśveśabhaṃ cet khalu viśvarūpā || *2* ||
#brāhmabhaṃ -Rohiṇī, ativṛtyā-19, kanyā-Virgo, mṛgaṃ- Mṛgaśirā, netra-2, viśveśabhaṃ- Ãrdrā, viśvarūpā-13
tatastulāvānapi vahnitulyaḥ punarvasuṃ cāpi gurorbhamindram |
sārpaṃ[1] *yadā madhyagataṃ prapaśyet tulādharopi kṣitipāṃśatulyam* || *3* ||
#tulā-Libra, vahnitulyaḥ-3, punarvasuṃ-Punarvasu, gurorbha-Puṣyā, indram-14, sārpaṃ-Ãśleṣā, kṣitipāṃśa-16
maghā yadodeti savṛścikopi vedāṃśayukto'tra vicitrametat |
aho na jāne śivarājadhānyāḥ kiṃ caiṣa bhānāṃ mahimāvicitram || *4* ||
#maghā-maghā, vṛścikopi- Scorpio, vedāṃśa-4
bhāgyaṃ yadā sopi dhṛtiprayuktaḥ ceduttarā syāt saraso dhanuṣmān |
karaṃ yadā sopi kṛtiprayuktaḥ citrāṃ yadāsau nṛpabhāgabhāk syāt || *5* ||
#bhāgyaṃ- Pūrvāphālguṇī, dhṛtiprayuktaḥ-18, Uttarā- Uttarāphālguṇī, raso-6, dhanuṣmān- Sagittarius, karaṃ-Hastā, kṛti-20, citrāṃ- Citrā, nṛpa-16
Svātī yadāsau makaro'yamāṃśabhogī viśākhāṃ sa dhṛtiprasiddhaḥ |
kuṃbhopi caṃdrāṃśabhugatra maitraṃ śākraṃ yadāsau vasubhāgabhāk syāt || *6* ||
#Svātī-Svātī, makaro- Capricorn, yamāṃśa-2, viśākhāṃ-Viśākhā, dhṛti-18, kuṃbha-Aquarius, caṃdrāṃśa-1, maitraṃ-Anurādhā, śākraṃ- Jyeṣṭa, vasu-8
[2]*mūlaṃ yadā cotkṛtibhogayukto yadāṃbubhaṃ vā tithibhāgayuktaḥ* |
minopi vaiśvaṃ yadi sā kṛtiḥ syāt grāhyaṃ yadāsau vikṛti prayuktaḥ|| *7* ||

mūlaṃ=Mūlā, utkṛti-26, āṃbubhaṃ- Pūrvaṣādhā, tithi-15, vaiśvaṃ- Uttarāṣādhā, kṛtiḥ-20, vikṛti-23
minopi has been read as *mīnopi.*
yadā tu madhye śravaṇaṃ sa meṣoviśvāṃśaśeṣo vasubhaṃyadā syāt |
vṛṣoniraṃśo yadi vāruṇaṃsyād vedāṃśayogo mithunepi citram || 8 ||
śravaṇaṃ-Śravaṇa, meṣo- Aries viśvāṃśaśeṣo(30-14 =17), vasubhaṃ-Dhanistā, vṛṣo-Taurus, niraṃśo-zero vāruṇaṃ- Śatabiṣā, vedāṃśa-4, mithuna-Gemini
yadā japādapratimāṃ khamadhye tvāśāṃśamātraṃ mithune'tra dṛṣṭam |
kimatra tarkaḥ kila caiṣa karkaḥ pūrṇāṃśako veti nacedupātyaḥ || 9 ||
japādapratimāṃ- Pūrvābhādrā, tvāśāṃśam-10, mithuna- Gemini, karkaḥ-Cancer, pūrṇāṃ-zero
sa eva karkaḥ saguṇaḥ kalājño āntyabhaṃ[1] *madhyagataṃ prapaśyet ||*
khamadhyabhādaṣṭamabhasya rāśiḥ pāṭhakramāt lagnamiha pradiṣṭaṃ || 10 ||
karka =- Cancer, guṇaḥ-3, āntyabhaṃ- Revatī
pūrvobhijidbhe vasupaṃcakaṃ tu maitre mṛge cādibhe paraḥ syāt || 11-1 ||
#abhijidbhe-abhijit, vasupaṃcakaṃ-58, pūrvobhijidbhe vasupaṃcakaṃ mṛge cādibhe paraḥ syāt- when Abhijit is on the east Mṛgaśirā is on the west

Footnotes

1: Not clearly legible,
2: We have swapped these lines for a meaningful interpretation.

Dr B.S.Shylaja hails from Bengaluru. After completing an MSc in Physics at Bangalore University. At the Indian Institute of Astrophysics 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 infrared 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 and guiding students for research in this area. 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, old paintings and such unconventional records.

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). Another work of seventeenth century '*Grahanamukura*', also has been translated, edited and is being printed. She is currently guiding the work related to the study of medieval period manuscripts from the collection of the Oriental Research Institute in Mysuru, India.

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 earlier observational techniques that were prevalent in India.

Dr. B.S. Shubha also hails from Bengaluru, and completed an MSc in mathematics at Bangalore University with fluid dynamics as her specialization. After a short tenure as a Lecturer at the MES College in Bangalore she continued her studies, working on an ancient manuscript, the *Mahādevī Dīpika*, and was awarded an MPhil by Samskrit University, Bangalore. She also obtained her doctorate from Samskrit University, for her study of the *Brahmatulya-udāharaṇam of* Viśvanātha (a sixteenth-century manuscript), under the guidance of Dr Vinay P and Dr B.S. Shylaja. She then expanded her studies to medieval period manuscripts by Ekanatha, Padmanabha and Sodhala.

Dr. Shubha worked as a Lecturer and Research Associate for more than three years at Purnapramati, a centre for integrated learning in Bangalore, her priority being Ancient Indian Mathematics and Indian Astronomy. She recently joined the Indian Institute of Astrophysics as a Visiting Scientist for the COSMOS Project, which involves the study of medieval manuscripts. She is currently working on a compilation of the works of Viswanatha, and other astronomical manuscripts.