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Unveiling *Viśvanātha* 's Mathematical Innovations in astronomy manuscripts

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Abstract. *Viśvanātha* is a well-known name in north India, who wrote many commentaries on different astronomy texts during 16th century. His work showcases methods for achieving accuracy in predictions of astronomical events. His contributions highlight an understanding in several key areas. He accurately accounted for the precession of the equinoxes, which is crucial in celestial calculations. He demonstrated iterative methods, refining approximations through repeated calculations to achieve remarkable accuracy. He emphasized geometrical constructions to visually represent celestial events. This approach was valuable for practical application of his calculations. Beyond many of his theoretical treatises and commentaries, the construction of an astrolabe, proves his commitment to practical observation. This blend of theoretical innovation and practical application marks him as a unique astronomer. Bringing the works of *Viśvanātha* work to light, not only enriches our understanding of 16th century Indian astronomy but also emphasizes the sophisticated scientific heritage that often remains hidden in historical shadows.

1. Introduction

The enduring popularity of many medieval texts can be attributed to the enhanced illustrations and commentaries written on them. A significant number of these works, particularly in the medieval period, are based on the foundational writings of Bhāskarācārya II. These commentaries are important because they not only update and refine parameters but also maintain the computational accuracy of the original texts, leading to more precise positions for planetary positions. The Seventeenth century text, *Brahmatulya udāharaṇam* (BU), serves as a prime example of this practice. With multiple mathematical innovations and concepts.

2. Author

Viśvanātha Daivajña, a 17th-century astronomer and commentator, was the son of *Divākara* of *Golagrāma* and worked with reference to Varanasi. In Śaka 1557 (1612 CE), he composed revered works, including *Gahanārtha Prakāśikā* on the *Sūryasiddhānta*, and wrote commentaries on major astronomical texts. He also constructed astrolabes, refer R. T. Gunther [1]. now preserved in museums.

3. Interrelation of Mathematical Concepts and Astronomical Events

Madhyamādhikara (mean longitudes), *Spaṣṭādhikāra* (true longitudes), *Tripraśna* (*dik* (direction), *desa*(longitude), *kala* (time), *Parvasambhava* (possibility of eclipse), *Candragrahaṇa*

(lunar eclipse), *Suryagrahaṇa* (solar eclipse), *Chāyādhikāra* (shadow of planets), *Udayāstādhikārah* (retrograde motion), *Śṛṅgonnati* (elevation of cusps), and *Grahayuti* (conjunction of planets) are some of the events with examples discussed in the manuscript. These are the standard ten concepts, found in the siddhantic texts which involve the mathematical concepts.

4. Principles governing the determination of mean planetary motion

To illustrate the procedures adopted in Indian astronomical texts for determining planetary positions, the first step involves calculating a fundamental reference parameter known as *ahargaṇa*. This parameter represents the total number of civil days elapsed from a fixed standard epoch up to the date under consideration. The computation of *ahargaṇa* forms the basis for all subsequent astronomical calculations and is concisely described in Rao [2].

Table 1. The positions of the planets after the corrections that are mentioned in the text on 12th May 1612.

Planet	Equation	Mean longitude values (°)	<i>Deśāntra</i> corrected values (°)	<i>abda-bija</i> corrected values (°)	<i>Ramabija</i> corrected values (°)
Sun(<i>ravi</i>)	$\left(A - \frac{13A}{903}\right) + K$ K = 329.216°	34.2877°	34.2747°	34.2747°	34.2747°
Moon(<i>candra</i>)	$\left(14A - \frac{14A}{17} - \frac{A}{8600}\right) + K$ K = 329.0971	200.75166°	200.5761°	200.5747°	200.5744°
Apogee of Moon (<i>ucca</i>)	$\left(\frac{A}{9} + \frac{A}{4012}\right) + K$ K = 135.2163°	312.2894°	312.2880°	312.2919°	312.2886°
Node of Moon (<i>pāta</i>)	$\left(\frac{A}{19} + \frac{A}{2700}\right) + K$ K = 287.4191°	316.1105°	316.1100°	316.1191°	316.1202°
Mercury (<i>Budha</i>)	$\left(4A + \frac{4A}{43} - \frac{A}{1421}\right) + K$ K = 81.2416°	297.7144°	299.7075°	299.7075°	299.7075°
Mars (<i>Kuja</i>)	$\left(\frac{11A}{21} + \frac{11A}{52444}\right) + K$ K = 231.4058°	81.435°	81.3777°	81.3858°	81.3861°
Venus (<i>śukra</i>)	$\left(\frac{16A}{7451} + \frac{16A}{10}\right) + K$ K = 258.0986°	133.9233°	133.9022°	133.9152°	133.9155°
Jupiter (<i>Guru</i>)	$\left(\frac{A}{12} - \frac{A}{4227}\right) + K$ K = 64.0141°	130.4283°	130.4272°	130.4255°	130.4277°
Saturn (<i>Śani</i>)	$\left(\frac{A}{30} + \frac{A}{9367}\right) + K$ K = 123.723°	325.8569°	325.8566°	325.8566°	325.8566°

Using the same principles an illustrative example cited in the text corresponds to Śaka 1534, *Vaiśākha Māsa, Pūrṇimā tithi*, which aligns with 12 May, 1612 CE, yielding a computed value of *ahargaṇa*, $A = 156762$. To account for the difference between the epochal positions and the desired date, a corrective term, known as *Kṣepaka (dhruvaka)* is used. This term is added to the calculated mean values to obtain the true positions of the planets (*spaṣṭa*).

This is denoted by K in all the equations in Table 1, which are different for each planet. Expressed solely in degrees for clarity, with *deśāntara* (longitude), and *abda bīja* (annual) corrections applied. *Viśvanātha* mentions *Rāmacandra Ācārya's* refinement using the *Nālikā Yantra* to enhance observational accuracy in manuscripts.

After obtaining mean longitude (*kṣepaka*-corrected), *manda saṃskāra* is applied to account for orbital eccentricity, yielding *manda sphuṭa* (true longitude). For the Sun and Moon, this uses the sine of *manda kendra* from *mandocca*, successively refining mean positions described in Shukla [3].

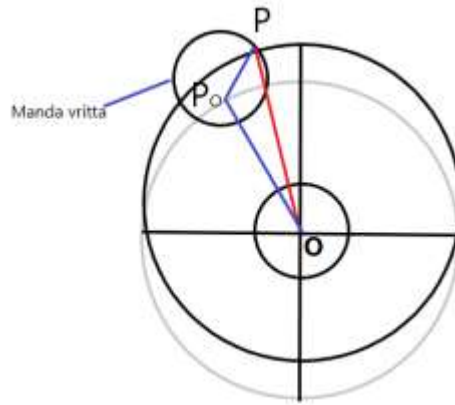


Figure 1. O is the center of the observer, P is the position of the planet before applying the manda correction, P_0 is the position of the planet after applying the correction.

5. Trigonometric formulae

In Sanskrit astronomical texts, *bhuja* and *koṭi* correspond to what we now refer to as the sine and cosine of a right-angled triangle. As shown in Figure 2, AB is called the *bhuja* (base or adjacent side), and AO is called the *koṭi* (perpendicular or opposite side) for the angle AOB. The trigonometric ratio sine is represented by the arc EB and is termed *jya* or *bhuja jya* represented by Rsine (*bhuja*).

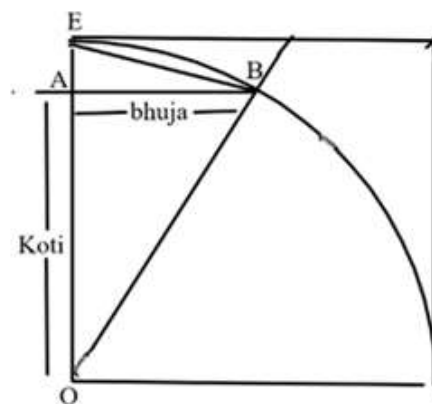


Figure 2. In the right-angled triangle AOB, inside the circle of radius R, the arc EB is called the bhuja jya. It is also written as Rsine (AOB).

The term *bhuja* denotes the angle (*kendra*) whose sine is required. Since traditional sine tables covered only 0° – 90° , conventions using quadrant properties were applied for larger angles. *Viśvanātha* adopts similar quadrant definitions, comparable to modern trigonometry. He formulates these rules concisely in the form of a verse, as follows:

*trīyūnaṃ bhujaḥ syat tryādhikena hīnam bhāradham ca bhārdhadhikam vibhārdham ||
 navādhikenonitam arkabham ca bhavēcca koṭistrigrham bhujonam ||*

meaning: If *kendra* is under three *rāśis* (90°), it is the *bhuja*. In the second quadrant, *bhuja* = $180^\circ - kendra$; in the third, *bhuja* = *kendra* – 180° ; in the fourth, *bhuja* = $360^\circ - kendra$, reflecting quadrants. This procedure is essentially analogous to the method employed in modern quadrant-based sine computations.

6. Iterative process

The iterative procedure, termed *asakṛt karma* or *parāvarta*, proceeds through successive stages (*prathama*, *dvitīya*, etc.) until arcsecond accuracy is attained. For instance, Mars longitude

Table 2. Tabulated values of iteration of mars for *manda* correction (anamoly).

Mars (<i>Bhauma</i>) <i>manda</i> correction Degrees ($^\circ$)	
First iteration (<i>Pratama Parivarta</i>)	314.8316
Second iteration (<i>Dvitiya Parivarta</i>)	334.4122
Third iteration (<i>trītiyā Parivarta</i>)	334.4130
Fourth iteration (<i>caturtī Parivarta</i>)	334.4130
Fifth iteration (<i>pañcamī Parivarta</i>)	334.4130

(334.413°) results from this method, inferred through detailed eclipse computations, including timing determinations.

7. Notable features in eclipse calculations

The *Brahmatulya Udāharaṇam* (BU) provides a detailed mathematical framework for computing the occurrence and characteristics of a lunar eclipse. The procedure begins with the determination of *ahargaṇa*, the fundamental time parameter used to calculate the mean longitudes of the Sun (*ravi*) and Moon (*candra*). A series of systematic corrections, *deśāntara*, *udayāntara*, *manda*, and *cara* are applied to these mean values to obtain the true (*spaṣṭa*) positions of the celestial bodies. Using these true positions, BU derives the instantaneous motions (*spaṣṭa gati*) of the Sun and Moon, essential for computing the *parva* (the exact instant of opposition corresponding to the full moon).

The method further incorporates the calculation of day and night durations (*Dinamāna*, *Rātrimāna*) and divisors (*hara*) to refine the hour angle (*nata*), through an iterative process, *asakṛit karma*, ensuring temporal accuracy. Subsequent steps involve the computation of the Moon's latitude (*sara*), and the apparent diameters (*bimba*) of the Sun and Moon, derived from their true daily motions. The Earth's shadow (*bhūbhā*) is also expressed in *aṅgula*, serving as the key parameter in determining the partial and total durations (*sthiti* and *marda*) of the eclipse.

The mathematical treatment extends to the evaluation of *valana*, comprising *akṣavalana* (due to terrestrial latitude) and *ayanavalana* (due to obliquity) which enables geometric verification of the eclipse through graphical representation (*parilekhana*). Finally, the magnitude or *grāsa* is computed using geometric relations involving the diameters of the Moon, the Sun, and the Earth's shadow.

8. Geometrical constructions

The geometrical procedure to depict the eclipse as a diagram is called *parilekhana*. This provides a method for the verification of calculations. Thus, this drawing represents the directions of the *sparśa* and *mokṣa* on the *bimba* of the moon. While it is possible to estimate this precisely in degrees generally it suffices to declare in terms of cardinal directions such as *agenya* (South East). *Parilekhana* on orientation of crescent moon known as *Śṛṅgonnati* is also seen in the text Shubha .et. all [4]. The text also has a reference of a special 11 verses indicating the method to find the ascensional difference of stars during night time as seen in Shylaja, [5], retrograde motion Shylaja [6].

9. Discussion

The inferred corrections reveal the mathematical depth of eclipse computations. *Bija* denotes corrections, including annual and parity adjustments, while precession is derived from the computed *ayanāṃśa*. *Viśvanātha* refines these up to the eclipse date, enhancing precision.

Though elaborate, the iterative procedure is systematic and rigorous. From *ahargaṇa* to true planetary positions, interlinked formulations integrate arithmetic, algebra, and geometry. Successive approximations and layered corrections demonstrate notable computational sophistication and mathematical insight in traditional Indian astronomy.

A detailed and critical analysis of these procedures is therefore essential to fully comprehend the intricate mathematical logic woven into them. Such an exploration not only brings to light the methodological precision of ancient astronomers like *Viśvanātha* but also underscores their profound understanding of mathematical modelling in the interpretation of celestial phenomena.

10. Conclusion

Viśvanātha's iterative refinements demonstrate remarkable mathematical rigor and precision. He integrates positional astronomy with systematic computation and geometric visualization of celestial phenomena. His work on constructing the astrolabe exemplifies the union of theory and practice. Together, these contributions highlight the intellectual depth and scientific sophistication of sixteenth-century Indian astronomy.

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