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ARTICLE

Computation of planetary geocentric latitudes and declinations based on the *Sūryasiddhānta* algorithm

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Abstract
The classical Indian astronomical text, the *Sūryasiddhānta*, provides a comprehensive framework for calculating the positions of celestial bodies through a set of well-defined, planet-specific procedures. While the computation of true planetary positions involves both longitudes and latitudes, each governed by distinct rules and corrections, while the determination of the true geocentric longitudes (*nirayaṇa*) for any given time and location was already presented in our previous study. Expanding upon that foundation, the present study addresses the computation of true geocentric latitudes and declinations of the planets, employing the algorithm outlined in the *Sūryasiddhānta*. The methodology is applied to calculate the planetary latitudes and declinations at the time of sunrise on March 30, 2025, for Mandi, Himachal Pradesh. The results are compared with the geocentric latitudes of the planetary data from Stellarium to evaluate the precision and reliability of the traditional algorithm, offering insights into its applicability for contemporary astronomical modeling.

Keywords *Sūryasiddhānta* · Astronomical model · Angular motion · Angular position · Longitude · Latitude · Declination · *Krānti* · *Śara* · *Vikṣepa* · *Manda* · *Śīghra* · *Pāta* · Epicycle · Mathematical model

1 Introduction

Traditionally in India, the *Jyotiṣa Śāstras* are regarded as the foremost among the six *Vedāṅgas—Śikṣā, Vyākaraṇa, Nirukta, Chandas, Jyotiṣa*, and *Kalpa* (Gosvami, 2007). The corpus of *Jyotiṣa Śāstra* is further divided into three principal branches: *Gaṇita* (mathematical astronomy), *Samhitā* (astrological and cosmological texts), and *Hora* (predictive astrology). Among these, the *Gaṇita* or mathematical section is considered the most fundamental, as it provides the computational basis for determining all astronomical parameters. Furthermore, *Jyotiṣa Gaṇita Śāstras* themselves are traditionally classified into four types: *Siddhānta, Mahātantra, Tantra*, and *Karaṇa*. This categorization is noted in the text *Vākyakaraṇa* (Sarma and Sastri, 1962, p. 7).

> तत्र सिद्धान्त-महातन्त्र-तन्त्र-करणभेदेन गणितस्कन्धस्य चतुर्विधत्वम् ।
>
> *tatra siddhānta-mahātantra-tantra-karaṇabhedena gaṇitaskandhasya caturvidhatvam* |
>
> There are four divisions among the mathematical astronomy (*gaṇitaskandhasya caturvidhatvam*), namely, the *siddhānta, mahātantra, tantra* and *karaṇa*.

Among the four divisions of Indian astronomy, the *Siddhāntas* are held in the highest regard, as they detail the motions of celestial bodies and the computation of astronomical parameters from the beginning of creation to the end of a *kalpa* (Samanta, 1899). In contrast, texts categorized as *Karaṇa, Tantra*, and *Mahātantra* typically offer simplified procedures and formulae applicable only within a limited time frame—usually the duration of a *Caturyuga* or the current *Kaliyuga*, or sometimes even shorter durations starting from the recent epochs within the current *Kaliyuga* (Venketeswara Pai et al., 2018).

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For a *Jyotiṣa-śāstra* to be classified as a *Siddhānta*, it must present calculations and principles valid across an entire *kalpa*, which spans a thousand *Caturyugas*.[1]

As a result, a *Siddhānta* text typically begins with an ancient epoch—dating back to the beginning of Brahmā's day or *kalpa*—and systematically presents detailed procedures for computing planetary positions, eclipses, and related astronomical phenomena. Thus, Indian astronomy, as codified in the *Jyotiṣa Gaṇita* texts, encompasses the computation of planetary longitudes and latitudes, conjunctions, tabulated Rsine values, *pañcāṅga* elements (*tithi, karaṇa, nakṣatra, yoga*, and *vāra*), the determination of directions, time and location, projection of solar and lunar eclipses, phases of the Moon, and much more (Shukla, 1957).

In contrast, *Mahātantra, Tantra*, and *Karaṇa* texts present computational formulae applicable over relatively short durations. This is because the *madhyas* (mean eastward motions of planets relative to the fixed stars) and the *śīghroccas* (Epicyclical anomalies around the mean positions) of the planets periodically align with the start of the zodiac (i.e., the beginning of the *Aśvinī* constellation) within a *caturyuga* or even shorter intervals—such as at $\frac{1}{4}^{\text{th}}$ or $\frac{1}{12}^{\text{th}}$ of a *caturyuga*. Here, the zodiac (*bhagaṇa-cakra*) is defined as a 360° stellar belt consisting of 27 constellations (e.g., *Aśvinī*, each covering approximately 13.33°) and/or 12 zodiac signs (e.g., *Meṣa*, each spanning 30°).

However, the *mandoccas* (slow epicyclical components centered on the mean positions) and the *pātās* (nodal points where planetary orbits intersect the ecliptic) do not align with the *madhyas* and *śīghroccas* at the end of any *yuga* within a *kalpa*. Despite this, *Karaṇa*-type texts offer simplified or abridged computational models by referencing *ahargaṇa* (day counts) from a recent epoch and employing *dhruvakas* (epoch-specific constants) to limit computational errors. In contrast, Siddhānta texts begin from the cosmic epoch of creation and often prescribe long-term corrections—known as *bīja* adjustments—to minimize accumulated errors over vast timescales.

Previous translations of the *Sūryasiddhānta*—notably by Burgess (1858), Pandey (1999), and Gosvami (2007)—along with summaries of other astronomical treatises by Subbarayappa and Sarma (1985) and Sarma and Sastri (1962), and Pingree (1996), have provided concise algorithms for a variety of astronomical computations. Recognizing the need to consolidate these individual computational steps, our earlier study (Pandu, S., Bhalla, P., Behera, L., et al., 2025) presented a unified procedure for determining the planetary positions of all visible planets, incorporating their respective longitude corrections and associated astronomical parameters.

That study systematically outlined the foundational astronomical constants, including the mean motions of the planets expressed in terms of complete revolutions over a *Caturyuga* (4,320,000 solar years) or a *Kalpa* (4,320,000,000 years). It then detailed the calculation of the number of days elapsed (*ahargaṇa*) since the time of creation, referenced to mean midnight at Laṅkā—a hypothetical location at the intersection of the Earth's equator and the Indian prime meridian (latitude 0°, longitude 0°) (Pāṇḍya, 1991). Using this *ahargaṇa*, the mean longitudes of the planets were computed, followed by the derivation of their true positions (i.e., true longitudes) for a given location by applying the necessary corrections to the mean longitudes. To compute the true longitudes of the planets, the *Sūryasiddhānta* prescribes a series of corrections applied to their mean longitudes. First, the *deśāntara-saṃskāra* is applied to determine the mean longitude at mean midnight for the observer's local place. This is followed by the *manda-saṃskāra*, or equation of the center correction, to obtain the true longitude at mean midnight for that location.[2] Additionally, the correction for the equation of time, caused by the eccentricity of the

[1] Verse 17 of the *Kāla Varaṇanam* section in the *Siddhānta Darpaṇa* specifies the essential criteria that a *gaṇita* text must fulfill to be acknowledged as a *Siddhānta*.

> यत्र त्रुट्यादि कालः प्रलयचरमकः खेचराणां प्रचारः
> प्रश्नाचैवोत्तराणि द्विविधगणितमध्युद्भवो भूतराशेः |
> स्थानं भूभग्रहादे ग्रहण खगयुति ज्या धनुष्कर्मयत्र
> क्षेत्रायं गद्यते सद्गणक गणवरैरेष सिद्धान्त उक्तः ||

> *yatra truṭyādi kālaḥ pralayacaramakaḥ khecarāṇāṃ pracāraḥ*
> *praśnācaivottarāṇi dvividhagaṇitam adhyudbhavo bhūtarāśeḥ* |
> *sthānaṃ bhūbhagrahāde grahaṇa khagayuti jyā dhanuṣkarmayatra*
> *kṣetrāyaṃ gadyate sadgaṇaka gaṇavaraireṣa siddhānta uktaḥ* ||

> For a *Jyotiṣa Gaṇita* text to be regarded as a *Siddhānta*, it must encompass the description of celestial motions from the moment of creation (*truṭyādi*) to the end of a *kalpa* (*pralaya caramakaḥ*), include questions with their answers, incorporate two branches of mathematics, explain the creation of living beings, detail the positions (*sthānam*) of the Earth and celestial bodies, and address phenomena such as eclipses, conjunctions, tabulated sines, and arcs. (Simha, 1899)

[2] For Sun and Moon, only full *manda* correction is required. However, for the remaining five planets—Mars, Mercury, Jupiter, Venus, and Saturn—the *Sūryasiddhānta* outlines a more elabo rate four-step correction process:

1. Apply half *śīghra-phala* to planet's mean longitude,
2. Apply half *manda-phala* to the resulting value,
3. Apply full *manda-phala*, computed based on step 2, to the planet's mean longitude,
4. Finally, apply full *śīghra-phala* to the resulting value obtained from step 3.

According to the *Sūryasiddhānta*, the *manda* correction represents the effects of orbital eccentricity and ellipticity in planetary motion, while the *śīghra* correction illustrates the shift from a geocentric to a heliocentric frame of reference.

ecliptic—termed the *bhujāntara-saṃskāra*—is applied to adjust the computed longitudes to reflect the true midnight at the observer's location. (Shukla, 1957)

Continuing the methodological framework established in our previous study for computing planetary positions, the present paper aims to update the mathematical model with the procedure for determining the true latitudes of the planets. In this work, certain modifications have been introduced to the traditional algorithm to enhance the precision of the computed planetary positions for a given time and location.

The proposed model is exemplified through the computation of the true planetary latitudes for *Caitra-śukla-pratipadā* of 2025 CE (30th March 2025, corresponding to 1946 of the *Śaka* Era). These computed results are evaluated against data obtained from Stellarium to assess the model's accuracy. Whereas the preceding study was primarily concerned with calculating true longitudes within the *nirayaṇa* (sidereal) framework—the central element of the model—this investigation emphasizes the derivation of *nirayaṇa* latitudes. Additionally, the model integrates the *ayanāṃśa* correction, as prescribed in the *Sūryasiddhānta*, to convert the *nirayaṇa* (sidereal) coordinates into *sāyana* (tropical) longitudes and latitudes.

To begin with, let us define a few key astronomical terms used throughout this paper.[3]

Just as the *mandocca* and *śīghrocca* generate the *manda* and *śīghra* corrections to a planet's mean longitude, the *pāta* gives rise to two key components of celestial position: the latitude (*vikṣepa* or *śara*) and the declination (*krānti*). This relationship is captured in the expression: *krāntir janakaḥ pātaḥ*—"the *pāta* is the origin of declination."

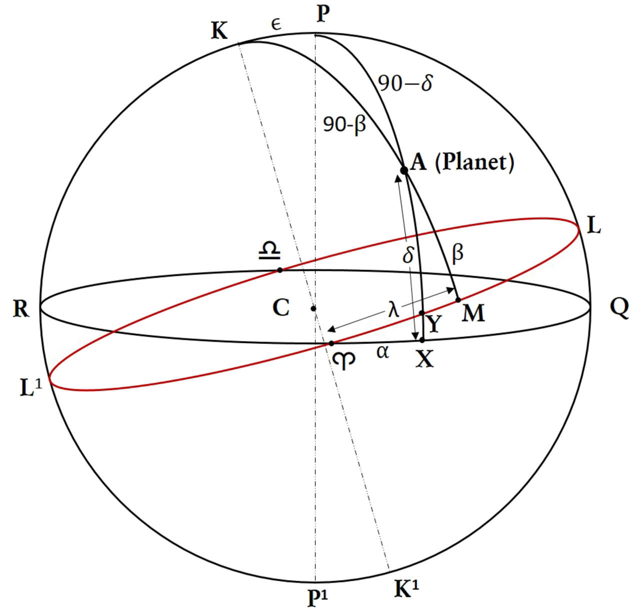


Fig. 1 Pictorial depiction of *krānti*, *śara* and *vikṣepa*

The **mean declination** (*madhyama-krānti*) is defined as the North–South angular difference (*dakṣiṇottara-antara*) between a planet's true position on the ecliptic and its corresponding projection onto the celestial equator (*viśuvad-vṛtta*). That is:

graha-sthāna viśuvad-vṛttayorantaram madhyama-krāntiḥ

Meanwhile, the **latitude** (*śara*) is the visual North–South angular difference between the actual disk (*bimba*) of the planet (Ref. Fig. 1) and its projection on the ecliptic (*krānti-vṛtta*):

graha-sthāna biṃbayorantaram śaraḥ[4]

Similarly, the angular distance from the ecliptic to the actual disk (*bimba*) of the planet along the circle of declination is known as the deflection or ***vikṣepa*** (*graha-sthāna biṃbayorantaram*), which is also considered as the celestial latitude in the case of texts like *Sūryasiddhānta* Venketeswara Pai and Shylaja (2016).

Finally, the **true declination** (*spaṣṭa-krānti*) is obtained by algebraically adding or subtracting the mean declination and the latitude:

madhyama-krānti śarayoḥ saṃskāreṇa spaṣṭa-krāntirucyate

Spaṣta-krānti = *madhyama-krānti* ± *śara*,

[3] A **solar month**: is defined as the period during which the Sun traverses one zodiac sign or *rāśi*—that is, the interval from one *saṅkrānti* (solar ingress) to the next. According to the *nirayaṇa* (sidereal) system, a solar year consists of 12 solar months, corresponding to the 12 *rāśis*: *Meṣa* (0°–30°), *Vṛṣabha* (30°–60°), *Mithuna* (60°–90°), and so on.

A **lunar month**, by contrast, is the interval between two successive Sun and Moon conjunctions (*amāvasyā*). A lunar year similarly comprises 12 lunar months, traditionally named *Caitra*, *Vaiśākha*, and so on.

A **tithi** is a fundamental lunar day, defined as every 12° of angular separation between the Sun and the Moon. Since a full lunar month spans 360° of relative motion between the Sun and the Moon, it consists of 30 *tithis*. These include, for example, *pratipadā* (0°–12°), *Dvitīyā* (12°–24°), *Tṛtīyā* (24°–36°), with the fifteenth being *Pūrṇimā* (168°–180°) and the thirtieth being *Amāvasyā* (348°–360°).

The daily motion of the planets from east to west is referred to as the *paścāt-gati* (daily westward motion). In contrast, their apparent motion relative to the background of the constellations, which themselves move westward faster, results in an observed eastward drift of the planets, termed *prāk-gati* (mean eastward motion). Within this framework, if a planet appears to move from east to west with respect to the stars, this motion is designated as *vakra-gati* (retrograde motion).

[4] *śara* refers to the angular distance of a celestial object north or south of the ecliptic.

where

δ (AX): true declination (*spaṣṭa-krānti*),
δ_m (YX): mean declination (*madhya-krānti*),
AY: deflection from ecliptic (*vikṣepa*),
β (AM): latitude (*śara*), λ (ϒM): longitude,
ϒY: *dhruvaka*, α (ϒX): right ascension.

Thus, there is a difference between *śara* and *vikṣepa* (Ref. Fig. 1). However, sometimes in mathematical computations they are considered same by neglecting the difference between them, especially in the case of planets because the orbital inclinations are very small small.[5]

2 Mean revolutions of the planets

The first chapter of the *Sūryasiddhānta* (*madhyamādhikāraḥ*) outlines the mean angular motions of the planets within the zodiac. It also details the average angular motions of key orbital elements: *mandocca, śīghrocca*, and *pāta*. These mean motions (see Table 1) are essential for estimating the approximate positions of planets in the *nirayaṇa* zodiac—measured either from the beginning of the first *nakṣatra* (*Aśvinī*, 0°) or the end of the last *nakṣatra* (*Revatī*, 360°).

According to the *Sūryasiddhānta*, all celestial bodies exhibit a continuous daily motion from east to west, known as the daily angular westward motion (*paścāt-gati*). However, because the average westward angular movement of the moving stars (constellations) exceeds that of the planets, the planets appear to move eastward relative to the stellar backdrop. This apparent relative motion is termed the mean eastward motion (*prāk-gati*).

Verses 29–33 and 41–44 of Chapter 1 in the *Sūryasiddhānta* enumerate the number of mean eastward revolutions completed by the *madhya* (mean planet), *śīghra, manda*, and *pāta* elements of each planet during a *caturyuga* (see Table 1).

Since the number of westward revolutions of the constellations (*bhagaṇa*), measured in the clockwise direction, is 1,582,237,828 over a *caturyuga*, we can determine the number of risings (i.e., apparent westward revolutions) of each planet (R_{WW}) during this period by subtracting the number of eastward revolutions (R_{EW}) of that planet:

$$R_{WW} = 1,582,237,828 - R_{EW}. \tag{1}$$

Furthermore, the number of days a planet takes to complete one full revolution through the zodiac (D_{Zodiac}) can be calculated by dividing the number of risings of the Sun ($R_{WW|Sun}$) by the number of eastward revolutions of that planet:

$$D_{Zodiac} = \frac{R_{WW|Sun}}{R_{EW}} = \frac{1,577,917,828}{R_{EW}}. \tag{2}$$

These values are presented in Table 2.

Table 1 The Eastward revolutions of the planets *madhya, śīghra, manda*, and *pāta* in a Caturyuga

Planet	Madhya	Śīghra	Manda	Pāta
Sun	4,320,000		0.387	
Moon	57,753,336		488,211	232,234
Mars	2,296,832	4,320,000	0.204	0.214
Mercury	4,320,000	17,937,060	0.368	0.488
Jupiter	364,220	4,320,000	0.900	0.174
Venus	4,320,000	7,022,376	0.535	0.903
Saturn	146,568	4,320,000	0.039	0.662

Table 2 Mean Eastward and Westward Revolutions and the Number of days required to cover the Zodiac

Planet	R_{EW}	R_{WW}	D_{Zodiac}
Nakṣatras	–	1,582,237,828	366.2588
Sun, Venus, Mercury	4,320,000	1,577,917,828	365.2588
Mercury's Śīghrocca	17,937,060	1,577,917,828	87.9697
Venus' Śīghrocca	7,022,376	1,577,917,828	224.6986
Moon	57,753,336	1,524,484,492	27.3217
Mars	2,296,832	1,579,940,996	686.9975
Jupiter	364,220	1,581,873,608	4332.3206
Saturn	146,568	1,582,091,260	10,765.7731
Rāhu–Ketu	232,234	1,582,470,066	6794.3998

3 Mean longitude of the planets

The *Nirayaṇa* longitudes of the planets are measured with reference to the first point of the *nakṣatra Aśvinī*, a fixed point on the ecliptic (zodiac) near the star Zeta Piscium, marking the end of *Revatī nakṣatra* (Shukla, 1957). Alternatively, these longitudes may be described as measured from the beginning of *Meṣa-rāśi*. To compute the *Nirayaṇa* longitudes, an epoch has been defined in which the mean longitudes of all planets and associated astronomical entities were simultaneously zero. The *Sūryasiddhānta* considers the "beginning of creation" as this epoch, which occurred 1,955,880,000 years prior to the commencement of the current *Kali-yuga*. At this epoch—corresponding to midnight at Laṅkā, a hypothetical location with 0 latitude and 0 longitude—the *madhyas, mandoccas, śīghroccas*, and *pātas* of

[5] Thus, in the context of the *Sūryasiddhānta* the coordinates of *yogatārās* (junction stars) are considered as polar longitudes and latitudes. The term *dhruvaka* is used for longitude, and *vikṣepa* is used for latitude in this case.

all planets were aligned at 0°, marking the start of *nakṣatra Aśvinī* (0°–13.33°) or *Meṣa-rāśi* (0°–30°) (Gosvami, 2007).

The number of days elapsed since the epoch is known as the *ahargaṇa*. *Sūryasiddhānta*, Chapter 1, Verses 22 and 23, describes the total number of years (and hence the total number of days) that had elapsed by the time the *Sūryasiddhānta* was narrated by an *aṃśa* (partial manifestation) of *Sūryadeva* to Maya. According to the text: "Starting from the beginning of the current *kalpa*, six *Manvantaras* along with their respective *sandhis* (transitional periods) were completed. Within the current (seventh) *Manvantara*, 27 *caturyugas* and the *Kṛta-yuga* of the twenty-eighth *caturyuga* had just been completed." By subsequently adding the number of years elapsed in the 28th *Tretā, Dvāpara*, and the current *Kali-yugas*, one obtains the total number of years elapsed up to any desired instant.

Since the *Kali-yuga* is believed to have commenced in 3102 BCE, and as the *caitra-śukla-pratipadā* of 2025 CE occurs before the Sun enters into *Meṣa-saṅkrānti*, the calculation of elapsed years must only include completed years up to 2024 CE. Therefore, the total number of years elapsed since the beginning of Brahmā's *kalpa* up to this point are as follows:

Total Number of Years Elapsed

$$\begin{aligned} &= (6 \times 71 + 7 \times 0.4 + 27.9) \times 4,320,000 + 5126 \\ &= 1,972,949,126. \end{aligned}$$

Siddhānta Śiromaṇi (Chapter 1, Verse 28) and *Sūryasiddhānta* (Chapter 1, Verse 24) describe the timeline for the manifestation of various living beings and the initiation of planetary motion. According to these texts: "From the beginning of Brahmā's day (*kalpa*) to the creation of immobile and mobile beings—such as trees, animals, humans, demons, and *devatās*—along with the stars and planets, 47,400 *devatā* years (equivalent to 17,064,000 human years) had elapsed." This interval, known as *sṛṣṭi-kāla* (creation time), denotes the span from the beginning of the *kalpa* to the moment when celestial motions and living beings came into existence. By subtracting this *sṛṣṭi-kāla* from the total number of years elapsed (as previously calculated), we determine the years that have passed since the onset of planetary motions. Multiplying this result by the number of days in a year yields the total number of days—termed *ahargaṇa*—that have elapsed from the epoch (the beginning of creation) up to midnight of *Meṣa-saṅkrānti* in 2025 CE.

Total Number of Years Elapsed from the Creation

$$\begin{aligned} &= 1,972,949,126 - 17,064,000 \\ &= 1,955,885,126. \end{aligned}$$

The total number of civil days elapsed until mid-night (*ahargaṇa*) and the number of hours elapsed after the mid-night until the start of 2025 CE *Meṣa-saṅkrānti* (CD_m) are computed by multiplying the total number of years elapsed with the total number of civil days in a solar year,[6]

$$\begin{aligned} CD_m &= 1,955,885,126 \times 365.2587565 \\ &= 714,404,168,943.386 \\ &= 714,404,168,943 \text{ days } 9 \text{ h } 15 \text{ min } 50 \text{ s.} \end{aligned}$$

As per *Sūryasiddhānta* (Chapter 1, Verse 50), at the beginning of creation, all the planets were in conjunction and simultaneously entering *Meṣa*, resulting in a celestial alignment that marks the midnight at the Indian prime meridian, which passes through the cities of Ujjain and Laṅkā (*laṅkāyām ārdharātrikaḥ*). Further, based on the verses 48 to 50 of the same chapter, which outline the number of lunar *tithis* in a *caturyuga*, the total number of lunar *tithis* elapsed till 2025 CE *Meṣa-saṅkrānti* (LT_m) are computed as,

$$\begin{aligned} LT_m &= \frac{714,404,168,943.386 \times 1,603,000,080}{1,577,917,828} \\ &= 725,760,188,298.336. \end{aligned}$$

Lunar tithi at 2025 CE Meṣa-saṅkrānti:

$$= remainder\left(\frac{725,760,187,928.336}{30}\right) = 18.336$$

$$(caitra\text{-}kr̥ṣṇa\text{-}caturthī, 4th\ tithi\ of\ kr̥ṣṇa\text{-}pakṣa).$$

Since the *Meṣa-saṅkrānti* of 2025 CE occurred on *caitra-kṛṣṇa-caturthī*, the required number of civil days elapsed for the start of *caitra-śukla-pratipadā* is calculated by subtracting the number of solar days equivalent to these eighteen lunar *tithis* from the total number of civil days elapsed for the beginning of 2025 CE *Meṣa-saṅkrānti*.

Equivalent Solar days and hours:

$$\begin{aligned} &= \frac{18.336 \times 1,577,917,828}{1,603,000,080} = 18.04882355 \\ &= 18 \text{ days } 1 \text{ h } 10 \text{ min } 18 \text{ s.} \end{aligned}$$

Thus, the total number of civil days and the number of hours elapsed after the mid-night until the start of 2025 CE *caitra-śukla-pratipadā* (CD_c),

[6] The total number of civil days in a solar year (D_y) are obtained by dividing the total number of civil day in a *caturyuga* by the total number of years in a *caturyuga*

$$D_y = \frac{1,577,917,828}{4,320,000} = 365.2587565.$$

$$\begin{aligned} CD_c &= 714,404,168,943.386 - 18.04882355 \\ &= 714,404,168,925.337176 \\ &= 714,404,168,925 \text{ days } 8 \text{ h } 5 \text{ min } 32 \text{ s.} \end{aligned}$$

Corresponding day during the Week

$$\begin{aligned} &= remainder\left(\frac{714,404,168,925.337}{7}\right) \\ &= 6.337\ (Saturday,\ 29^{th}\ March,\ 2025). \end{aligned}$$

According to the *Sūryasiddhānta*, the Indian Prime Meridian is described as passing through the ancient cities of Rohītaka, Kurukṣetra, and Avantī (modern-day Ujjain). Notably, the sacred site of Mahākāleśvara Jyotirliṅga in Avantī, located at 23.1827° N latitude and 75.7682° E longitude (relative to the Greenwich Prime Meridian), lies precisely at the intersection of the *Sūryasiddhānta's* Prime Meridian and the Tropic of Cancer. Thus, the time of Ujjain (Indian Prime Meridian) at the start of the *caitra-śukla-pratipadā tithi* is around 8 h 5 min 32 s in the morning.

In comparison, the City of Mandi in Himachal Pradesh is situated at a geographic coordinate of 31.7754° N, 76.9861° E. The longitudinal difference (*deśāntara*) between Ujjain and Mandi is therefore 1.2179° to the east. Since each degree of longitude corresponds to 4 min of time, this longitudinal difference translates to approximately 0.00338 days, or 4.8716 min. This correction must be added to the elapsed civil days to obtain the total number of days elapsed for the true mean time of the starting of the desired *tithi* at the given location (Mandi).[7]

$$Deśāntara = \frac{1.2179°E \times 0.5}{180°E} = 0.003380833,$$

$$\begin{aligned} Time\ at\ Mandi &= 8.0859375 - 0.00338 \times 24 \\ &= 8.004744\ (8 \text{ h } 0 \text{ min } 17.1 \text{ s}). \end{aligned}$$

However, the corrected number of civil days elapsed for the mean sunrise at Mandi the next morning at 6:01 AM (30th April, 2025, Sunday) are computed by incorporating both the longitudinal and diurnal time corrections.

$$\begin{aligned} &= 714,404,168,926 + 0.003380833 + 0.25069444 \\ &= 714,404,168,926.2540753 \\ &= 714,404,168,926 \text{ days } 6 \text{ h } 5 \text{ min } 52 \text{ s.} \end{aligned}$$

[7] Though, entire India follows same time, for mathematical computations, the starting time of the given *tithi* at Mandi is computed applying the *deśāntara* correction.

Table 3 Mean positions (in degrees) of the planets and their *śīghrocca*, *mandocca* and *pāta* in the zodiac

Planet	Mean	Śīghrocca	Mandocca	Pāta
Rāhu	338.337	0	0	270
Ketu	158.337	180	180	90
Moon	341.119	195.4459	0	248.337
Mercury	342.129	220.4772	159.9292	290.671
Venus	342.129	79.8785	175.8984	329.644
Sun	342.129	77.2953	0	270.000
Mars	120.568	130.0471	342.1293	310.049
Jupiter	61.137	171.3844	342.1293	349.666
Saturn	328.358	236.6267	342.1293	10.337

The mean daily motions mentioned in Table 1 were used in computing the mean (approximate) positions of the planets

3.1 Mean position of the planets

The mean positions (POS) of the planets in the zodiac (*madhyama-graha-sādhanam*) are computed by multiplying the above computed elapsed number of civil days (*ahargaṇa*) with the daily angular motion (Rev_{daily}) of the respective planets.

$$Rev_{ahargaṇa} = Rev_{daily} \times ahargaṇa, \tag{3}$$

$$POS = fractional\ part(Rev_{ahargaṇa}) \times 360°. \tag{4}$$

The positions of the *madhyas, śīghroccas, mandoccas*, and *pātas* of all the planets at the sunrise of *caitra-śukla-pratipadā* of 2025 CE are computed and presented in Table 3.

Verses 67–68 of Chapter 1 further describes the maximum deflection (*vikṣepa*) of the planetary orbits from the ecliptic.

SS 1.67-68
भचक्रलिप्ताशीत्यंशैः परमं दक्षिणोत्तरम् ।
विक्षिप्यते स्वपातेन स्वक्रान्त्यन्तादनुष्णगुः॥ १.६७ ॥
तन्नवांशं द्विगुणितं जीवस्त्रिगुणितं कुजः।
बुधशुक्रार्कजाः पातैर्विक्षिप्यन्ते चतुर्गुणम् ॥ १.६८ ॥

bhacakraliptāśītyaṃśaiḥ
paramaṃ dakṣiṇottaram |
vikṣipyate svapātena
svakrāntyantādanuṣṇaguḥ || 1.67 ||
tannavāṃśaṃ dviguṇitaṃ
jīvastriguṇitaṃ kujaḥ |
budhaśukrārkajāḥ pātair
vikṣipyante caturguṇam || 1.68 ||

The maximum deflection (latitude) of the Moon from the ecliptic in the northern or southern direction, due to its nodal inclination (*pāta*), is given as the 80^{th} part of the *bha-chakra* (the celestial circle), expressed in units of *kalās*. Based on this, the maximum deflection of Jupiter is $\frac{2}{9}^{th}$ of the Moon's deflection, while that of Mars is $\frac{3}{9}^{th}$ of the Moon's maximum deflection. The maximum deflections of Mercury, Venus, and Saturn are each $\frac{4}{9}^{th}$ of the Moon's maximum deflection.

The Moon is said to deviate northward or southward (*parama dakṣiṇottara vikṣepa*) from the mean declination or from the ecliptic (*madhya-krānti* or *krānti-vṛtta*) due to the effect of its node (*pāta*), to the extent of the 80th part of the *bha-cakra* (i.e., the celestial circle of 360° or 21,600 *kalās*). Which is,

$$\textit{Parama dakṣinottara vikṣepa} = \frac{360° \times 60'}{80}$$
$$(\textit{of Moon}) = 270' \ (\textit{or } 4.5°).$$

This means that due to the influence of the Moon's *pāta*, its position can deviate northward or southward from the ecliptic by up to 270 *kalās*. Similarly, the *pātas* of the other *grahas* also cause deflection from the ecliptic. Based on the Moon's deflection, the *parama vikṣepa* (maximum deflection) for the other planets is given proportionally:

- Jupiter: $\frac{2}{9}^{th}$ of Moon's deflection → $60' = 1°$,
- Mars: $\frac{3}{9}^{th}$ of Moon's deflection → $90' = 1.5°$,
- Mercury, Venus, and Saturn: $\frac{4}{9}^{th}$ of Moon's deflection → $120' = 2°$.

Thus, the maximum deflection (*parama vikṣepa*) of the planets are—Moon: 270′ (4.5°), Mars: 90′ (1.5°), Mercury: 120′ (2.0°), Jupiter: 60′ (1.0°), Venus: 120′ (2.0°), and Saturn: 120′ (2.0°). These deflections are crucial in determining the planetary latitudes (*vikṣepa-jyā*) for accurate positional astronomy in the Indian tradition.

While the first chapter of the *Sūryasiddhānta* primarily focuses on the computation of the mean longitudes of the planets, Chapter 2 offers a systematic exposition of the procedures required to compute the true longitudes and latitudes of the planets. This chapter lays out, step by step, the various causes and classifications of planetary motion, the determination of Rsine values (*jya*), and outlines four essential corrections that must be applied to derive the true longitudes of the planets. Notably, Chapter 2 also delves into the methods for calculating planetary true latitudes and declinations, which forms the central focus of this study.

4 Causes of planetary motions

Our previous study (Pandu, S., Bhalla, P., Behera, L., 2025) detailed the multi-step procedures involved in performing the four essential corrections to the mean eastward angular positions in order to derive the true longitudes of the planets in the zodiac. These computations required additional corrections based on the supplementary motions of the planetary elements, such as *śīghrocca* and *mandocca*. The mean, *śīghrocca* and *mandocca* represent the positions of the planets in their respective orbits or epicycles. Their corresponding motions—either faster or slower—introduce variations to the mean eastward motion over short or extended intervals, thereby refining the planetary longitudes. Similarly, the position of the *pāta* causes the orbit of the planet to deviate from the ecliptic, thereby generating its latitude. In this study, however, we now turn our attention to the step-by-step procedure for determining the latitudes of the planets based on their true longitudes. The first 11 verses of Chapter 2 of the *Sūryasiddhānta* explain how the mean motion of a planet is influenced by these imperceptible yet significant celestial reference points: the *mandocca*, *śīghrocca*, and *pāta*, each fixed in the zodiac.

SS 2.1
अदृश्यरूपाः कालस्य मूर्तयो भगणाश्रिताः ।
शीघ्रमन्दोच्चपाताख्या ग्रहाणां गतिहेतवः ॥ १ ॥

adṛśyarūpāḥ kālasya
mūrtayo bhagaṇāśritāḥ |
śīghramandoccapātākhyā
grahāṇāṃ gatihetavaḥ || 1 ||

The [entities] known as *śīghrocca, mandocca* and *pāta*, whose forms, belonging to time (*kālasya mūrtayaḥ*), are invisible (*adṛśyarūpāḥ*) and dependent on the movement of the constellations (*bhagaṇāśritāḥ*), are responsible for the motion of the planets (*gatihetavaḥ*).

The verse emphasizes that the invisible celestial points—namely, the *śīghrocca*, *mandocca*, and *pāta*—which themselves are dependent on the uniform motion of the constellations (*bha-cakra* or *krānti-vṛtta*), are responsible for the apparent movements and deflections observed in the planetary bodies. These imperceptible reference points introduce variations to the mean motion of the planets, thereby generating deflections that give rise to their true motion. It is through the influence of these entities that the otherwise uniform mean motion is perturbed, resulting in the complex paths observed in planetary dynamics.

SS 2.2
तद्वातरश्मिभिर्नद्धा स्तैस्सव्येतरपाणिभिः ।
प्राक्पश्चादपकृष्यन्ते यथासन्नं स्वदिङ्मुखम् ॥ २ ॥

tadvātaraśmibhirnaddhā
staissavyetarapāṇibhiḥ |
prākpaścādapakṛṣyante
yathāsannaṃ svadiṅmukham || 2 ||

The planets are bound by the winds, [which act] as rope (*vātaraśmibhiḥ*), of the invisible entities of *śīghrocca*, mandocca and *pāta* (*tat*), and they are pulled (*prākpaścādapakṛṣyante*) in their respective direction (*svadiṅmukham*) from the left-hand or right-hand side (*savyetarapāṇibhiḥ*).

The planets (and stars) are said to be bound to certain celestial reference points—*śīghra*, *manda*, and *pāta*—through subtle cords of air, known as *vātaraśmi*. These invisible cords metaphorically tether the planetary bodies to these guiding points in the zodiac. As a result, the planets are influenced by the pull of these entities when they come near them, whether in a clockwise or counterclockwise direction, and whether moving eastward or westward. The proximity to these reference points causes the planets to deviate from their mean paths, thereby explaining the observed variations in their motion.

SS 2.3
प्रवहाख्यो मरुत्तांस्तु स्वोच्चाभिमुखमीरयेत् ।
पूर्वापरापकृष्टास्ते गतिर्यान्ति पृथग्विधाः ॥ ३ ॥

pravahākhyo maruttāṃstu
svoccābhimukhamīrayet |
pūrvāparāpakṛṣṭāste
gatiryānti pṛthagvidhāḥ || 3 ||

A wind (*marutā*) known as *pravaha* draws the planets toward their respective *ucca*. As this wind exerts force in both the eastward and westward directions (*pūrvāparāpakṛṣṭāḥ*), it gives rise to the planets' distinct motions.

Planetary motions are further modulated by a celestial wind termed *pravaha*, which imparts a subtle impetus toward each planet's respective *ucca* position. In conjunction with the influences of the *śīghra, manda*, and *pāta* forces, this wind induces alternating eastward and westward displacements. The resulting interplay yields distinct (*pṛthak*) angular trajectories for the planets, causing deflections from their uniform mean motions.

SS 2.4
ग्रहात्प्राग्भगणार्धस्थः प्राङ्मुखं कर्षति ग्रहम् ।
उच्चसंज्ञोऽपरार्धस्थस्तद्वत्पश्चान्मुखं ग्रहम् ॥ ४ ॥

grahātprāgbhagaṇārdhasthaḥ
prāṅmukhaṃ karṣati graham |
uccasaṃjño'parārdhasthas
tadvatpaścānmukhaṃ graham || 4 ||

If the *ucca* is situated in the eastern half of the orbit, then the *ucca* pulls the planet eastwards (*prāṅmukhaṃ*). If the *ucca* is situated in the western half of the orbit, then it pushes the planet westwards (*paścānmukhaṃ*).

The verse explains that if the *ucca* (either *śīghrocca* or *mandocca*) of a planet is positioned in the eastern half of the orbit (*prāgbhagaṇārdha*, i.e., from 270° to 90°), it exerts an eastward pull on the planet. As a result, the true position of the planet moves ahead of its Mean Center (C, see Fig. 2). Conversely, if the *ucca* lies in the western half of the orbit (*aparārdha*, i.e., from 90° to 270°), it pulls the planet westward, causing the true position of the planet to lag behind the Mean Center (C).

SS 2.5
स्वोच्चापकृष्टा भगणात्प्राङ्मुखं यान्ति यद्ग्रहाः ।
तत्तेषु धनमित्युक्तमृणं पश्चान्मुखेषु च ॥ ५ ॥

svoccāpakṛṣṭā bhagaṇāt
prāṅmukhaṃ yānti yadgrahāḥ |
tatteṣu dhanamityuktam
ṛṇaṃ paścānmukheṣu ca || 5 ||

As much as the true planets are ahead of their mean positions in the east direction, the same amount is added to the mean (*dhana-saṃskāra*). Moreover, if the true planets are behind their mean in the west direction, the same amount is reduced from their mean (*ṛṇa-saṃskāra*).

When the planet (B, see Fig. 3) is pulled forward by the corresponding *ucca* (B′), the deflection is considered positive (*dhana*); whereas, when the planet is drawn backward, it is considered negative (*ṛṇa*). In other words, when the *ucca* pulls a planet eastward along its annual orbit, the

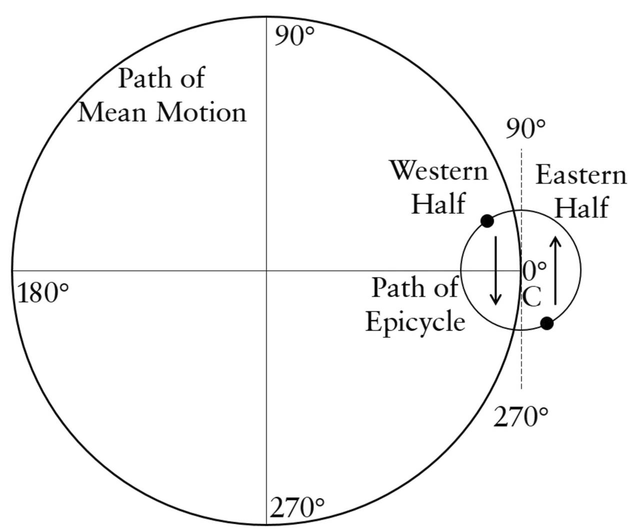


Fig. 2 *Manda* or *śīghra* Epicycle and it's effect on the Mean Motion of the Planet

planet gains in motion (B″). Conversely, when the *ucca* pulls the planet westward, the planet experiences a loss in its motion.

SS 2.6
मात् ।दक्षिणोत्तरयोरेवं पातो राहुश्च रंहसा ।
विक्षिपत्येष विक्षेपश्चन्द्रादीनामपक्रमात् ॥ ६

dakṣiṇottaratoyorevaṃ
pāto rāhuśca raṃhasā |
vikṣipatyeṣa vikṣepaś
candrādīnāmapakramāt || 6 ||

Rāhu, known as *pāta*, by its own prowess makes the Moon (*candra*) deviate from the ecliptic and go northward or southward. Similarly, *pāta* of the other planets causes them to deviate [from the ecliptic, *apakramāt*].

Similarly, just as described above, the *pāta*—the point of intersection between a planet's orbital path (*svavṛtta*) and the ecliptic (*krānti-vṛtta*)—is responsible for causing the planets to deviate northward or southward due to its own inherent attraction. The *pāta* (such as Rāhu and others) propels the planet away from the ecliptic point (*krāntyanta-bindu*) with considerable movement, resulting in a deflection in the north or south direction equal to the maximum angular deflection (*vikṣepa*). This deflection of a planet from its point of declination (*apakrama*) is referred to as the planet's latitude or deflection (*vikṣepa*) (Pandey, 1999).

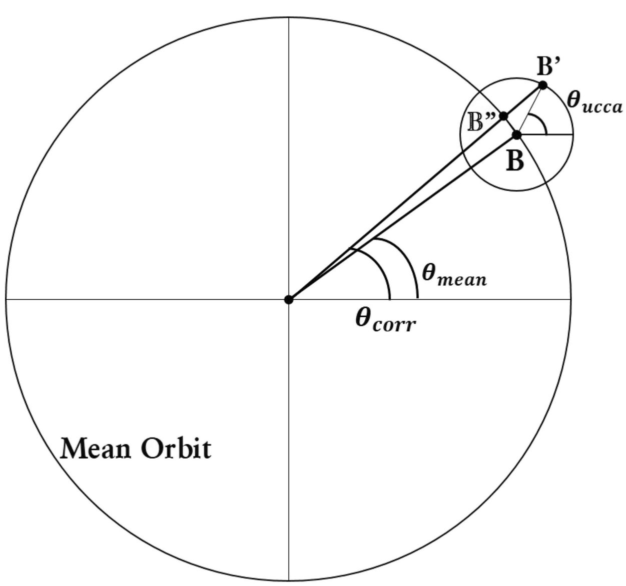


Fig. 3 Effect of *ucca* on planet's mean position

SS 2.7
उत्तराभिमुखं पातो विक्षिपत्यपरार्धगः ।
ग्रहं प्राग्भगणार्धस्थो याम्यायामपकर्षति ॥ ७ ॥

uttarābhimukhaṃ pāto
vikṣipatyaparārdhagaḥ |
grahaṃ prāgbhagaṇārdhastho
yāmyāyāmapakarṣati || 7 ||

If the *pāta* is less than six zodiac signs in the West direction (*aparārdhagaḥ*) from the planet, then the planet is attracted in the North direction (*uttarābhimukhaṃ*) and if it is less than six zodiac signs in the East (*prāgbhagaṇārdhasthaḥ*), then it attracts the planet in the South direction (*yāmyāyāmapakarṣati*).

As referred in Chapter 1, verses 43, 44, and 68 of the *Sūryasiddhānta*, the *pāta* is specified only for the Moon, Venus, Mercury, Mars, Jupiter, and Saturn. Their own *pāta* cause them to deviate from the ecliptic—northward or southward—by an amount equal to their respective deflections.

SS 2.8
बुधभार्गवयोशीघ्रात्तद्वत्पातो यथास्थितः ।
तच्छीघ्राकर्षणातौ तु विक्षिप्येते यथोक्तवत् ॥ ८ ॥

budhabhārgavayośīghrāt
tadvatpāto yathāsthitaḥ |
tacchīghrākarṣaṇātau tu
vikṣipyete yathoktavat || 8 ||

According to the aforesaid rules (*yathoktavat*), if the angular distance between the *pāta* and the *śīghrocca* of Mercury and Venus is less than six zodiac signs (i.e., 180°) either in the Eastern or Western direction, then these planets are subjected to a deflection in latitude—being drawn northward or southward due to the attraction of their respective *śīghroccas*.

The nodes (*pātaḥ*) of Mercury and Venus are positioned relative to their respective *śīghroccas* within the Eastern and Western halves of their orbits. Due to the attraction of the *śīghroccas*, Mercury and Venus experience deflection toward the North and South (*vikṣipyete*), in a manner similar to that described for the Moon and other planets (*yathoktavat*). Hence, the nodes of Mercury and Venus are said to lie on their *śīghrocca-vṛtta* (i.e., the circular path traced by their *śīghroccas*), denoted as *śīghroccavṛtte pātāvasthitiḥ*. In contrast, for Mars, Jupiter, and Saturn, the nodes are placed on the *mandasphuṭa-vṛtta* (the epicycle associated with the *mandocca*), as noted by certain authorities (*mandasphuṭavṛtta ityeke*) (Shukla, 1957).

SS 2.9
महत्वानमण्डलस्याऽर्कः स्वल्पमेवाऽपकृष्यते ।
मण्डलाल्पतया चन्द्रस्ततो बह्वपकृष्यते ॥ ९ ॥

mahatvānmaṇḍalasyā'rkaḥ
svalpamevā'pakṛṣyate |
maṇḍalālpatayā candrastato
bahvapakṛṣyate || 9 ||

Because of the largeness of it's orbit or disc (size, *maṇḍalasyā*), the Sun is less attracted [by its *mandocca*], whereas the Moon becomes more attracted due to the smallness of it's orbit or disc (size, *maṇḍala*).

Thus, because of the largeness (*gurutva*) of its size, the Sun is drawn away very little, while the Moon due to its smallness in size, is drawn away to a greater extent. This is because of the larger size of the Sun, the entities can only deviate him to a small extent. Because of the smaller size of the Moon, the entities deviate him to a larger extent.

SS 2.10
भौमादयोऽल्पमूर्तित्वात् शीघ्रमन्दोच्चसंज्ञितैः ।
दैवतैरपकृष्यन्ते सुदूरमतिवेगिताः ॥ १० ॥

bhaumādayo'lpamūrtitvāt
śīghramandoccasaṃjñitaiḥ |
daivatairapakṛṣyante
sudūramativegitāḥ || 10 ||

The planets, starting from Mars (i.e., Mercury, Venus, Mars, Jupiter, and Saturn), due to their relatively smaller size (*alpamūrtitvāt*), are drawn with greater movement and to a larger extent (*sudūram ativegitāḥ*) away from their regular mean paths by the divine entities (*daivataiḥ*) known as *śīghrocca* and *mandocca* (*śīghramandocca-saṃjñitaiḥ*).

The word *sudūraṃ* means that they are too far away (*bahu*), *ativegitāḥ* means that they are too fast (*vegayuktāḥ*), that means too quickly they go away from their mean position (*śīghram apakṛṣyanta*). In the text, the term *ativegitaiḥ* means very fast, and it is due to the divine entity known as *ucca* (*ucca-daivataiḥ*).

SS 2.11
अतो धनर्णं सुमहत्तेषां गतिवशाद्भवेत् ।
आकृष्यमाणास्तैरेवं व्योम्नि यान्त्यनिलाहताः ॥ ११ ॥

ato dhanarṇaṃ sumahat
teṣāṃ gativaśādbhavet |
ākṛṣyamāṇāstairevaṃ
vyomni yāntyanilāhatāḥ || 11 ||

Therefore, [the longitudes] of these [planets (*bhaumādi*)] have *dhana* (gain) and *ṛṇa* (loss) in their motion to a great extent (*sumahat*). Hence the planets, being attracted (*ākṛṣyamāṇaḥ*) by those entities, move in the celestial sphere (*vyomni*) carried on by the winds (*anilāhatāḥ*) and have different types of distinct deviations in their normal motion.

The text indicates that these planets, under the influence of the aforementioned celestial entities (*ucca-daivataiḥ*), occasionally advance ahead of their mean positions, while at other times they fall behind. Consequently, due to the dynamic influence of these entities—*śīghrocca, mandocca*, and *pāta*—the planets exhibit distinct and varied deflections from their regular mean motion. Even *Vivaraṇa* commentary suggests the same.

ataḥ sudūramapakrṣaṇād gativaśāduccagrahayoḥ anta rālagativaśadantarālamānavaśāt kendrabhūjānusāreṇa dhanarṇayoḥ bhujāphalayorādhikyaṃ bhavatītyarthaḥ | evaṃ tairuccaiḥ ākṛṣyamāṇāḥ pravahānilena cāhatāḥ grahāḥ vyomni yānti aparāṅmukhamityarthaḥ |

Therefore, due to the farther deviations (*sudūramapakrṣaṇād*) of the fast moving *uccas* of the planets, the *bhhja-phala* based on the distance between the mean position and the *ucca* position of planet (*kendrabhūjānusāreṇa*) corresponding to the deviation (*antarālamānavaśāt*) is added or subtracted (*dhanarṇayoḥ*) to the *bhujāphala* of the planets mean position. This means that the planets, being attracted (*ākṛṣyamāṇāḥ*) by the *ucca* due to the *pravaha* winds (*anilena*), move in the opposite direction (*yānti aparāṅmukham*) in the sky (*vyomni*) [sometimes, when the *bhhjāphala* due to *ucca* is negative].

Thus, verses 12–13 classify planetary motion into eight specific types—*vakra, anuvakra, vikalā, manda, mandatara, sama, śīghra*, and *śīghratara*, each characterized by unique dynamic behavior.

Chapter 1 of the *Sūryasiddhānta* lays the groundwork by presenting the mean angular motions of the planets, along with the associated motions of their *mandoccas, śīgroccas*, and *pātas* within the zodiac (*madhyamādhikāraḥ*). Through the eastward revolutions of these mean parameters—*madhya, śīgrocca, mandocca*, and *pāta*—the corresponding mean angular positions can be systematically determined. Building on this, Chapter 2 elaborates the methods for calculating the *manda, śīghra*, and *pāta* anomalies, and provides a comprehensive framework for deriving the true planetary positions in both longitude and latitude. The deviation of true longitudes from mean positions is computed using the locations of the *śīgrocca* and *mandocca*, whereas the displacement of planetary latitudes from the ecliptic is determined based on the position of the *pāta*. While our earlier study (Pandu, S., Bhalla, P., Behera, L., et al., 2025) focused on the derivation of true planetary longitudes, the present work concentrates on the accurate computation of true planetary latitudes.

Śūryasiddhānta, Chapter 2, Verse 14 explicitly states that the primary objective of the chapter is to describe the procedure for computing the true positions of the planets—namely, both their true longitudes and latitudes. Following this, after detailing the method for computing the twenty-four Rsine values within a quadrant, *Śūryasiddhānta* in Verse 29 proceeds to explain the computation of the *manda* and *śīghra* anomalies. Verses 34–37 then outline the standard dimensions of the *manda* and *śīghra* epicycles for the various planets. Verse 38 elaborates on how to derive the true or instantaneous dimension of a planet's epicycle. Verse 39 of the *Sūryasiddhānta* outlines the method for computing the *manda-phala* (correction due to the *mandocca*), while Verses 40–42 describe the procedure for determining the *śīghra-phala* (correction due to the *śīghrocca*). Both corrections follow a similar computational procedure.

The method employed for calculating both the *manda* and *śīghra* corrections is briefly summarized now. The angular difference between the *ucca* (either *mandocca* or *śīghrocca*) and the mean planetary position (or, in some cases, the previously corrected value) yields the *kendra*—also referred to as *mandakendra* or *śīghrakendra*, depending on the context.

$$kendra = ucca - mean. \tag{5}$$

Using this *kendra* compute the instantaneous or true or corrected circumference of the epicycle (*sphuṭa-paridhi*), which dynamically varies between the even or odd quadrant (P_{even} or P_{odd}) values of the *paridhi*. This periodic variation is essential in capturing the true nature of planetary motion as described in the epicyclic model. The maximum radius of the *sphuṭa-paridhi* ($P_{sphuṭa}$) indicates the maximum angular deviation of the true planetary position from its mean (or corrected mean) position, and thus plays a critical role in determining the extent of correction required for accuracy.

$$P_{sphuṭa} = P_{even} - (P_{even} - P_{odd}) \times |\sin(kendra)| \text{ (where kendra varies from } 0° \text{ to } 360°). \tag{6}$$

Thus, the *manda*-corrected orbit of the planet, when $\theta_{manda} = 0$, $\theta_{manda} > 0$ and $\theta_{manda} = 180°$ is illustrated in Fig. 4. As depicted, the planetary orbit experiences a shift in the direction of the *sphuṭa-manda* position, by a distance equal to the *sphuṭa-manda* radius (denoted as BB', $\frac{manda-paridhi}{2\pi}$). Consequently, the *manda*-corrected elliptical orbit, now centered at point A', becomes eccentric with respect to the center of the planet's mean circular orbit at point A. This displacement reflects the classical Epicyclical correction applied to the mean position, capturing the planet's apparent non-uniform motion as observed from the Earth. After calculating the *sphuṭa-paridhi* for both *manda* and *śīghra*, the first epicycle—with a radius (r) of $\frac{Sphuṭa-manda-paridhi}{2\pi}$ (BC)—is centered at the planet's mean position (B). The second epicycle—with a radius (r) of $\frac{Sphuṭa-śīghra-paridhi}{2\pi}$ (CD)—is centered at the *manda*-corrected (i.e., corrected mean) position (C). Thus, the planet's mean position advances along the mean orbit, while the *mandocca* and *śīghrocca* move along their respective epicycles, as depicted in Fig. 5.

After computing *sphuṭa-paridhi* of *manda* or *śīghra* epicycle based on the *kendra* (θ_{kendra}), the angular difference of planet's *ucca* (θ_{ucca}) and mean (θ_{mean}), compute the *ucca-phala* ($\theta_{ucca-phala}$) to determine the true or corrected position of the planet. The corrected longitude (θ_{corr}) is obtained by applying the *ucca-phala* as either an additive or subtractive correction to the mean longitude. This process is visually illustrated in Fig. 6.

$$Bhujajyā = r \times \sin(\theta_{kendra}), \tag{7}$$

$$Koṭijyā = r \times \cos(\theta_{kendra}), \tag{8}$$

where R (AB) is the radius of the Mean Orbit and r (BC) is the radius of the *ucca* epicycle. *Bhujajyā* (CE) is the arm perpendicular to θ_{kendra} and *kotijyā* (BE) is the arm adjacent to θ_{kendra}. The corrected radius ($R_{corr} = AC$) of the planet is computed as,

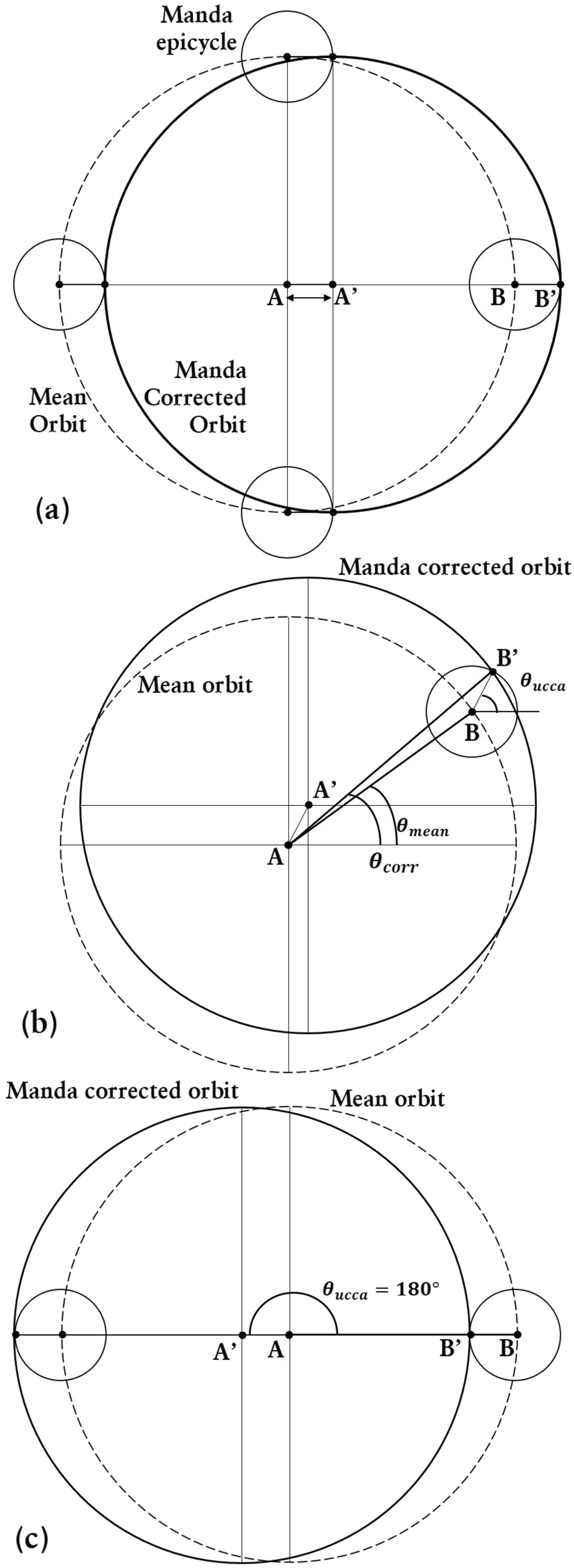
$$R_{uccakarṇa}(R_{corr}) = \sqrt{(R \pm koṭijyā)^2 + bhujajyā^2}, \tag{9}$$

$$\theta_{ucca-phala} = \sin^{-1}\left[\frac{Bhujajyā}{R_{uccakarṇa}\,(R_{corr})}\right], \tag{10}$$

$$\theta_{corrected} = \theta_{mean} \pm \theta_{ucca-phala}. \tag{11}$$

Chapter 2, Verse 43 of *Sūryasiddhānta* further outlines the sequential order in which the four essential corrections must be applied to the mean position of the planet (θ_{mean}) in order to obtain its true position. For the Sun and the Moon, only full *manda* correction is required. However, for the remaining five planets—Mars, Mercury, Jupiter, Venus, and Saturn—*Sūryasiddhānta* outlines a more elaborate four-step correction process. They are, (1) Apply half *śīghra-phala* to planet's mean longitude, (2) Apply half *manda-phala* to the resulting value, (3) Apply full *manda-phala* correction, computed based on step 2, to the planet's mean longitude, and (4) Finally, apply full *śīghra-phala* correction to the resulting value obtained from step 3.

Fig. 4 Effect of *manda* Correction upon the Mean Orbit of the Planet (dashed circle). *Manda* corrected orbit (thick circle) when **a** $\theta_{manda} = 0$, **b** $\theta_{manda} > 0$, and **c** $\theta_{manda} = 180$, which is elliptic and eccentric from the center of mean orbit (A) and shifted towards the *manda* position



In accordance with the procedure outlined above, the true longitudes of the planets for the sunrise of *caitra-śukla-pratipadā* of 2025 CE (Civil days elapsed: 714,404,168,926.254) for Mandi have been computed. The mean, *manda*, and *śīghra* positions of the planets (as shown in Columns 2 to 4) along with the respective values of the four corrections (Columns 5 to 8) are presented in Table 4. Subsequently, Table 5 provides the progressively corrected positions of the planets (in degrees) following each of the four corrections, as detailed in Columns 5 to 8. Figure 7 illustrates the true (corrected) positions of all the planets in the zodiac after the application of the four corrections, along with their corresponding *manda* and *śīghra* epicycles.

The four corrections applied to each of the individual planets are illustrated in six separate diagrams (Fig. 8). The mean, *manda*, and *śīghra* epicycles are represented by the black, red, and blue circles, respectively. As shown in the figures, the planet's mean position (1) first shifts to the *manda*-corrected position (2) as a result of the *manda* correction. Subsequently, the *śīghra* correction adjusts this to the final *manda-śīghra* corrected position (3), which represents the true or corrected location of the planet. The first diagram presents the mean and corrected positions of the Sun, Moon, Rāhu, and Ketu together, while the subsequent diagrams display the mean and corrected *manda* and *manda-śīghra* positions of the remaining planets.

After applying the IAU (the International Astronomical Union) value of the Precession of the Equinox, which is approximately −24.71325° (Ephemeris), to the *sāyana* longitudes obtained from the Stellarium software readings,[8] the resulting *Nirayaṇa* longitudes are compared with the *Nirayaṇa* longitudes obtained through the mathematical model for the same location and date. The comparisons and the corresponding errors are presented in Table 6.

Similarly, the *nirayaṇa* longitudes computed from the mathematical model for the sunrise of 16th August, 2025 CE (*śrāvana-kṛṣṇa-aṣṭamī*) at Mandi are compared with the *nirayaṇa* longitudes derived by subtracting the modern

[8] The Ecliptic Longitude values are taken from Stellarium software (https://stellarium-web.org/) as *Sāyana* longitudes. The corresponding *nirayaṇa* longitudes are derived by subtracting the modern (IAU) Precession of the Equinox (−24.71325°) for the year 2025 CE from the *sāyana* ecliptic longitudes: 18° 47′ 8.2″, 0° 3′ 21.3″, 358° 31′ 7.5″, 9° 33′ 43.1″, 112° 57′ 57″, 74° 40′ 31.9″, and 354° 15′ 6″, recorded for the sunrise of March 30*th* at Mandi.

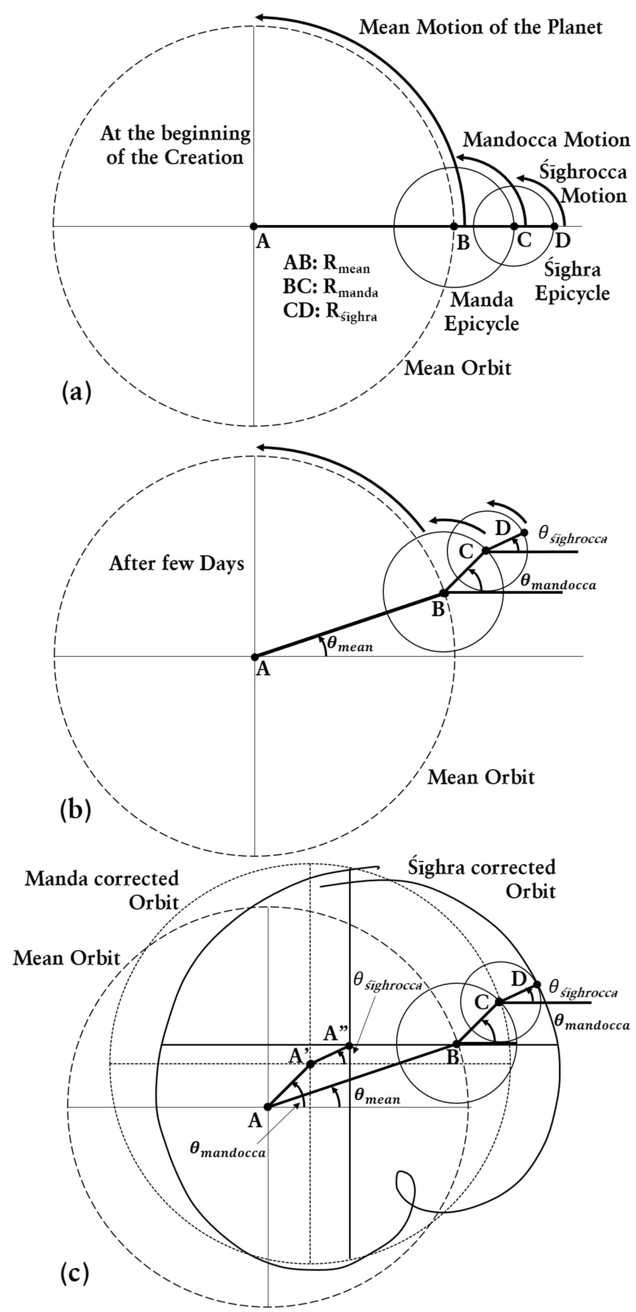


Fig. 5 **a** *Manda* and *Śīghra* epicycles (the two small circles) upon the mean orbit (dashed circle). **b** Movements of Mean, *Mandocca* and *Śīghrocca*. **c** The resultant planetary *manda* corrected (dotted circle) and *śīghra* corrected (thick circle) orbits. The mean of the planet is placed on a circular orbit (dashed circle) with a radius of $R = \frac{360^{\circ}}{2\pi}$ (AB) units, where the total circumference is considered to be 360°. Since the *manda-paridhi* and *śīghra-paridhi* values are expressed in degrees relative to their respective mean orbits, their corresponding radii (BC and CD) are also taken as $r = \frac{sphuṭa-paridhi}{2\pi}$

(IAU) Precession of the Equinox (−24.71325°) from the *sāyana* ecliptic longitudes of the Stellarium software[9] for

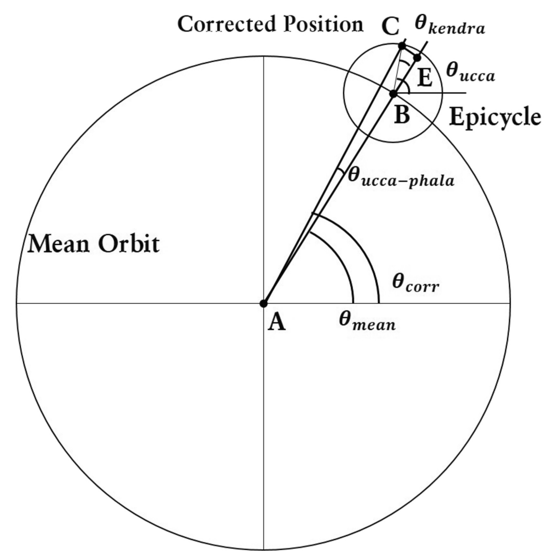


Fig. 6 Computation of *manda-phala* or *śīghra-phala*

the same location and time. The comparisons and the corresponding errors are presented in Table 7.

5 *Sāyana* longitudes (*ayanāṃśa-sādhanam*)

Śūryasiddhānta, Chapter 3, Verses 9 and 10, describe the method for determining the *ayanāṃśa* (i.e., the degrees of precession of the equinoxes) and its application to the planetary longitudes.

SS 3.9-10
त्रिंशत्कृत्यो युगे भानां चक्रं प्राक् परिलम्बते ।
तद्गुणाद्भूदिनैर्भक्ताद् द्युगणाद्यदवाप्यते ॥ 9 ॥
तद्दोस्त्रिघ्ना दशाप्तांशा विज्ञेया अयनाभिधाः ।
तत्संस्कृतादुग्रहात् क्रान्तिच्छायाचरदलादिकम् ॥ 10॥

triṃśatkṛtyo yuge bhānāṃ
cakraṃ prāk parilambate |
tadguṇādbhūdinairbhaktād
dyugaṇādyadavāpyate || 9 ||
taddostrighnā daśāptāṃśā
vijñeyā ayanābhidhāḥ |
tatsaṃskṛtādugrahāt
krānticchāyācaradalādikam || 10 ||

"In a *caturyuga*, the constellations (zodiac, *bhacakra*) regress eastwards (*prāk parilambate*) or oscillate between the east and west 600 times (i.e., 30 × 20 cycles, *triṃśatkṛtyaḥ*[10]). By multiplying this with

[9] The *sāyana* ecliptic longitudes are: 50° 45′ 12.5″, 125° 33′ 18.4″, 108° 31′ 46.2″, 143° 25′ 21.4″, 185° 40′ 28.1″, 104° 49′ 45.8″, and 1° 0′ 24.4″

[10] Multiply 30 with 20, *triṃśat sankhya ka kṛtir viṃśatiḥ* (Pandey, 1999).

Table 4 Computation of the four corrections (in degrees) of the planets (as per *Sūryasiddhānta* 2.40–42)

Planet	Mean position	Manda position	Śīghra position	Half-Śīghra correction	Half-Manda correction	Full-Manda correction	Full-Śīghra correction
Rāhu	338.2840	0	0	0	0	0	0
Ketu	158.2840	180	180	0	0	0	0
Moon	354.2949	195.5573	0	0	− 1.0023	− 2.0042	0
Mercury	343.1150	220.4772	164.0215	− 0.2655	− 1.9832	− 3.9508	− 3.0227
Venus	343.1150	79.8785	177.5005	− 15.6690	0.8241	1.7554	− 28.8935
Sun	343.1150	77.2953	0	0	1.0873	2.1744	0
Mars	121.0920	130.0471	343.1150	− 19.9216	2.3921	1.5177	− 30.6234
Jupiter	61.2197	171.3844	343.1150	− 5.3195	2.3921	4.9324	− 11.2580
Saturn	328.3911	236.6267	343.1150	0.7180	− 3.8157	− 7.6221	2.1536

Table 5 Computation of corrected positions (in degrees) of the planets for *caitra-śukla-pratipadā* of 2025 CE

Planet	Mean position	Manda position	Śīghra position	After Half Śīghra correction	After Half Manda correction	After Full Manda correction	After Full Śīghra correction (true position)
Rāhu	338.2840	0	0	338.2840	338.2840	338.2840	338.2840
Ketu	158.2840	180	180	158.2840	158.2840	158.2840	158.2840
Moon	354.2949	195.5573	0	354.2949	353.2926	352.2907	352.2907
Mercury	343.1150	220.4772	164.0215	342.8495	340.8663	339.1641	336.1414
Venus	343.1150	79.8785	177.5005	327.4460	328.2701	344.8704	315.9770
Sun	343.1150	77.2953	0	343.1150	344.2022	345.2894	345.2894
Mars	121.0920	130.0471	343.1150	101.1704	103.5624	122.6097	91.9863
Jupiter	61.2197	171.3844	343.1150	55.9003	58.2924	66.1522	54.8942
Saturn	328.3911	236.6267	343.1150	329.1092	325.2935	320.7691	322.9227

the number of days elapsed (*dinagaṇa* or *ahargaṇa*), and dividing the result by the total number of days in a *caturyuga* ($CY_{ahargaṇa}$), we obtain the number of precessional revolutions (*bhagaṇa*) along with the fractional part. Ignoring the completed revolutions, the remaining fraction corresponds to a Rsine value (as explained in Chapter 1). Multiplying this Rsine (*bhuja*) by 3 and dividing it by 10 yields the *ayanāṃśa* (i.e., the degrees of precession). After correcting the planet's longitude with this *ayanāṃśa*, the Rsine of declination (*krāntijyā*), apparent motion (*cara*),[11] etc., can then be determined."

Ayanāṃśa refers to the angular distance of the *ayana-bindu* (equinox point) from the fixed starting point of the zodiac. The *ayana-bindu* is defined as the intersection point of the Celestial Equator (*Nāḍī Vṛtta* or *Madhya Rekhā Vṛtta*)—which is the projection of the Earth's equator onto the celestial sphere—and the Ecliptic (*Krānti Vṛtta* or *Viṣuvad Vṛtta*), which is the apparent path of the Sun.

In the context of *ayanāṃśa* (precession of the equinoxes), ancient Indian astronomers held two distinct theoretical views regarding the motion of the *ayana-bindu* (the equinoctial point):

1. **Cakra-bhramaṇa (circular movement)**: This view posits that the *ayana-bindu* revolves uniformly in a circular path along the ecliptic. Scholars such as Munjāla Ācārya supported this model, wherein the *ayana-bindu* is considered to undergo a continuous, unidirectional motion akin to the concept of axial precession accepted by IAU.
2. **Dola-bhramaṇa (pendulum-like movement or oscillatory)**: This theory, upheld in classical texts like the *Sūryasiddhānta*, describes the movement of the *ayana-bindu* as an oscillation between ±27° relative to the starting point of *Meṣa-rāśi*. According to this model, the *ayana-bindu* progresses eastward from 0° to + 27°, then reverses its direction to return to 0°, continues westward to −27°, and again reverses to reach 0°, thus completing

[11] In ancient Indian astronomy, *cara* refers to the arc of the celestial equator that lies between the 6 o'clock circle (i.e., the local meridian at 90° from the eastern horizon) and the hour circle passing through a celestial body at the time of its rising.

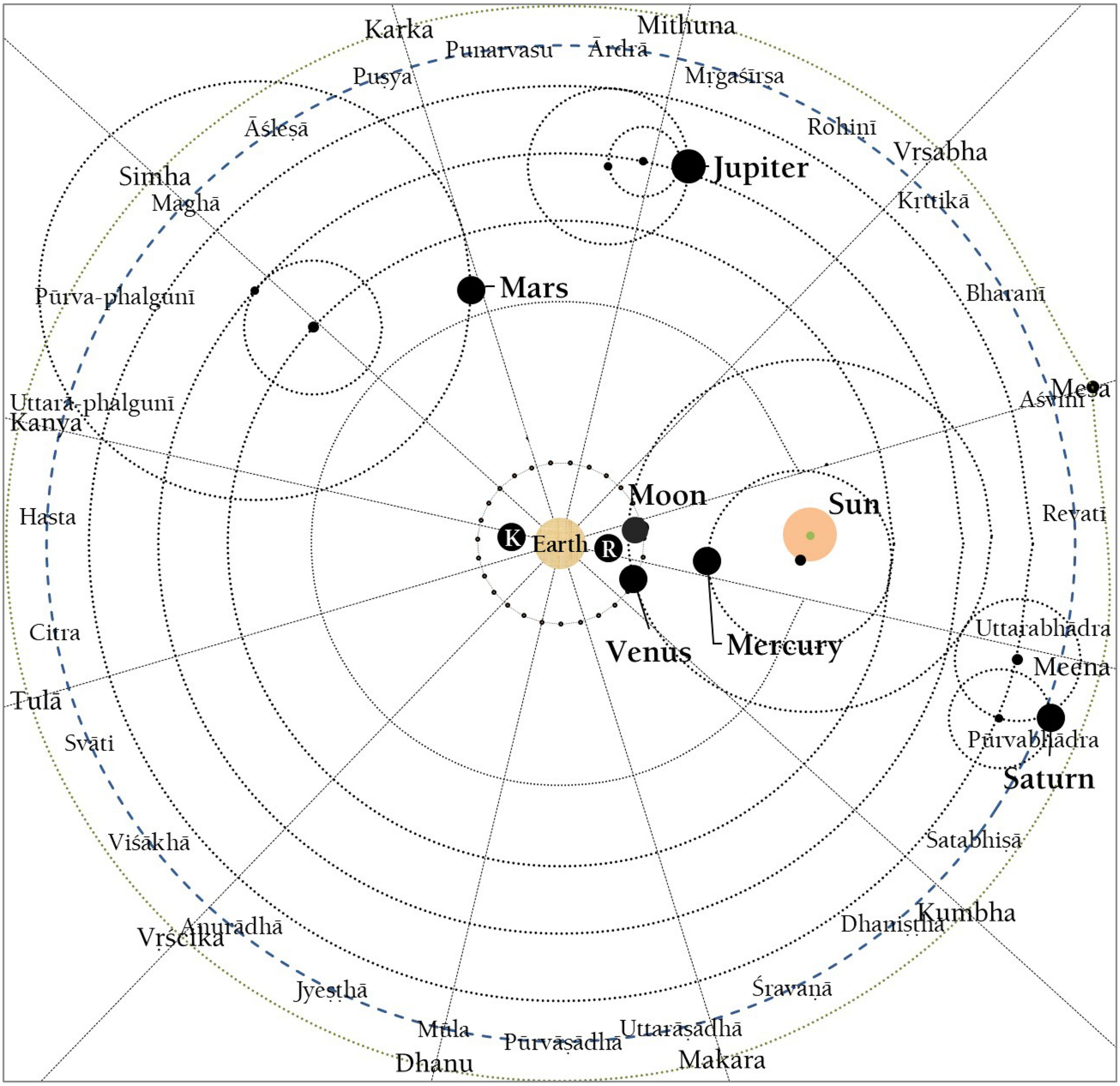
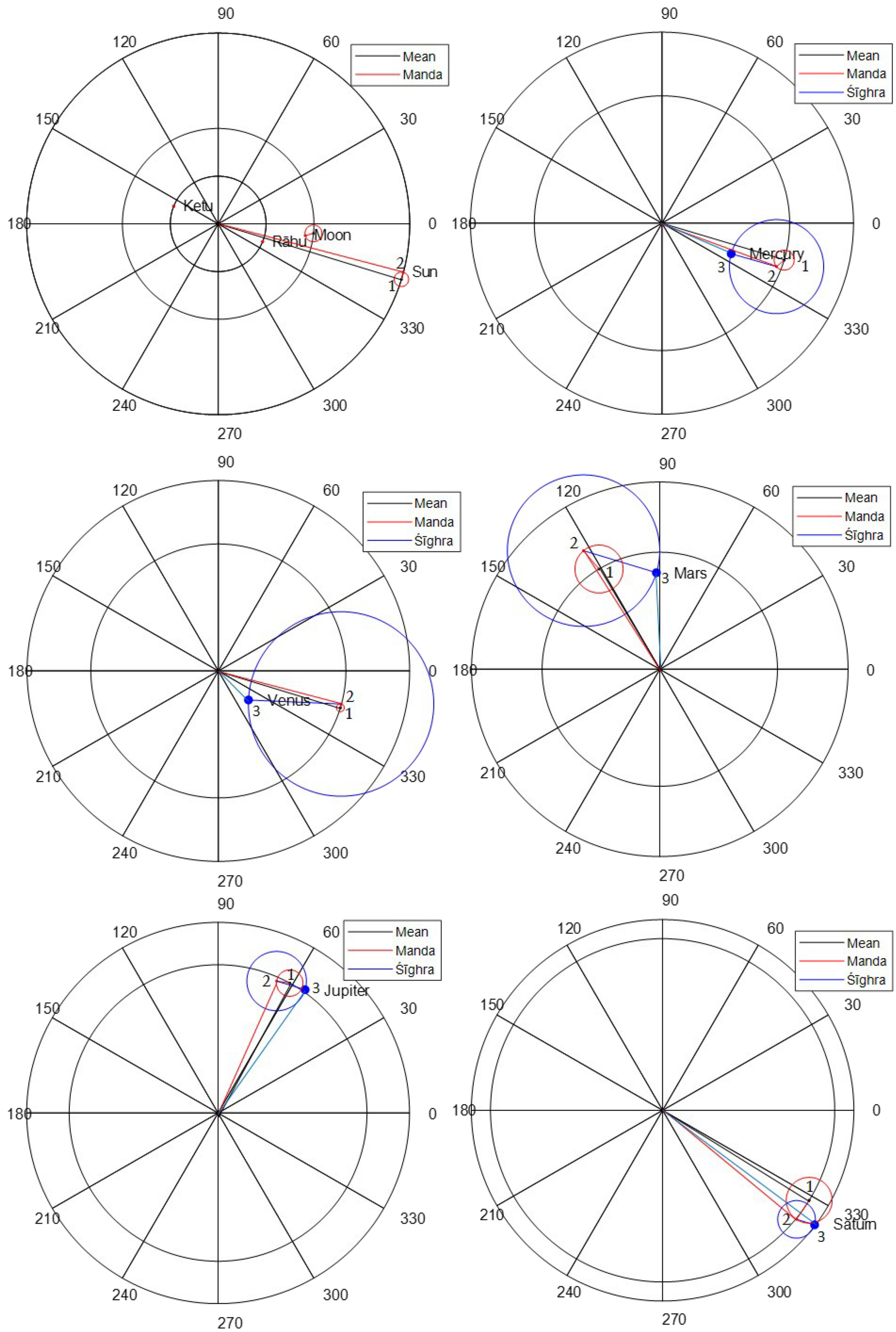


Fig. 7 The True Positions of the planets for the Sunrise of *caitra-śukla-pratipadā* of 2025 CE (30th May 30th, 2025) in Mandi (figure is drawn not to the scale in regards to the radius of the orbits, however the Figure is drawn to indicate the angular positions of the planets at the selected instant of time. 'R' indicates Rāhu and 'K' indicates Ketu. The first small circle around the planet's mean position is *manda* epicycle, and the second small circle around the planets *manda* position is the planet's *śīghra* epicycle. The ratio between the radius of the *manda* epicycle to mean orbit and *śīghra* epicycle to the mean maintained correctly)

a full oscillatory cycle. This motion is compared to the pendulum of a clock, swinging between its two extremes and back.

This divergence in cosmological understanding represents a significant contrast in the foundational models of ancient Indian astronomy. The *dola-bhramaṇa* model aligns with a cyclical view of time and cosmic order (Refer to the Fig. 9), while *cakra-bhramaṇa* reflects a more linear progression.

At the beginning of creation (*sṛṣṭi-ādi-kāla*), the *ayana-bindu* coincided with the starting point of the *Meṣa-rāśi* (i.e., *nirayaṇa meṣādi*) or the *Aśvinī* constellation (*nirayaṇa aśvinyādi*). Over time, this *ayana-bindu* gradually drifts eastward, reaching a maximum of + 27°, and then reverses



90
120
60
150
30
180
0
210
330
240
300
270
Mean
Manda
Śīghra
Ketu
Rāhu
Moon
Sun
Mercury
Venus
Mars
Jupiter
Saturn
1
2
3

◂**Fig. 8** *Manda* and *śīghra* corrected positions of the planets after the four corrections. Mean: black circle, *manda* corrected: red circle, and *śīghra* corrected: blue circle. Figure is drawn not to the scale in regards to the radius of the orbits. However the Figure is drawn to indicate the angular positions

direction westward, reaching up to −27° (or equivalently 333°), after which it resumes eastward motion. This cyclical oscillation is described in the *Sūryasiddhānta* as the precession of the equinoxes.

$$\begin{aligned} Ayan\bar{a}\dot{m}\acute{s}a\ Bhuja &= 360 \times \left(\frac{600 \times ahargaṇa}{CY_{ahargaṇa}} \right)_{rem}, \\ Ayana\text{-}calan\bar{a}\dot{m}\acute{s}a &= \frac{Ayan\bar{a}\dot{m}\acute{s}a\ Bhuja \times 3}{10} \\ &= \frac{Ayan\bar{a}\dot{m}\acute{s}a\ Bhuja \times 4 \times 27}{360} \\ &= 108 \times \left(\frac{600 \times ahargaṇa}{CY_{ahargaṇa}} \right)_{rem}. \end{aligned}$$

Hence, the *ayanāṃśa* is defined as the angular separation between the fixed starting point of the zodiac (*nirayaṇa meṣādi* or *aśvinyādi*) and the current position of the *ayana-bindu* (equinox). This value is essential in converting between the *sāyana* (tropical) and *nirayaṇa* (sidereal) longitudes of celestial bodies. The text further elaborates the computational procedure for determining the *ayanāṃśa* in accordance with the oscillatory theory, as described in the classical treatise, the *Sūryasiddhānta*.

Thus, to complete a full cycle of oscillation spanning 108° (i.e., $4 \times 27°$), the *ayana-bindu* requires approximately 7,200 years (i.e., $\frac{4{,}320{,}000}{600}$), assuming a constant rate of precession of 54 arc seconds per year ($= \frac{108° \times 60' \times 60''}{7{,}200}$). Consequently, it covers 27° in a single direction every 1800 years.

At the onset of the current *Kaliyuga* in 3102 BCE, the *ayana-bindu* was aligned with the beginning of the *Meṣa-rāśi* (*Meṣādi*). After progressing 27° eastward over 1800 years (in 1302 BCE), it again returned to *Meṣādi* (0°) after completing another 1800-year cycle in 499 CE (3600th year of *Kaliyuga*, $3600 - 3102 + 1$), coinciding with the year of the compilation of the Āryabhaṭīya. Since then, the *ayana-bindu* has been moving westward toward −27°. As of *Meṣādi* of 2025 CE, the *ayanāṃśa*-the angular separation between the *ayana-bindu* and *Meṣādi*-is approximately −22.89°.

$$\begin{aligned} Ayana\text{-}calan\bar{a}\dot{m}\acute{s}a &= 108 \times \left(\frac{600 \times ahargaṇa}{CY_{ahargaṇa}} \right)_{rem} \\ (of\ 2025\ CE) &= 108 \times \left(\frac{600 \times 5,126}{4,320,000} \right)_{rem} \\ &= 108 \times (0.711944)_{rem} \\ &= 76.89° \ (which\ is\ -22.89°). \end{aligned}$$

By the *Meṣādi* of the 5400th year of *Kaliyuga* (corresponding to 2299 CE), this value is expected to reach −27°. After this point, the *ayanāṃśa* will begin to decrease in magnitude, eventually returning to 0° by the 7200th year of *Kaliyuga* (corresponding to 4099 CE), marking a complete cycle of precessional reversal.

By applying the *ayanāṃśa* correction of –22.89°[12] to the previously determined *nirayaṇa* (sidereal) longitudes, we obtain the corresponding *sāyana* (tropical) longitudes of the planets. These calculated values are then compared with the *sāyana* longitudes provided by Stellarium software, as presented in Table 8.

Thus, after outlining the procedure for computing the *Nirayaṇa* and *sāyana* longitudes of the planets and comparing them with the *Nirayaṇa* and *sāyana* longitudes obtained from Stellarium software (as shown in Tables 6, 8), we now proceed to describe the method for determining the planetary latitudes and declinations.

6 Declination and latitude of the planets

Sūryasiddhānta Chapter 2 Verse 55 prescribes a correction to the longitude with the ascending node (*pāta*) of a planet to render it fit for the use in the calculation of the celestial latitude (*vikṣepa*) of a planet. Verses 56–57 give rules for finding the celestial latitude and the true declination of a planet.

SS 2.55
कुजार्किगुरुपातानां ग्रहवच्छीघ्रजं फलम् ।
वामं तृतीयकं मान्दं बुधभार्गवयोः फलम् ॥ 55 ॥

kujārkigurupātānāṃ
grahavacchīghrajaṃ phalam |
vāmaṃ tṛtīyakaṃ māndaṃ
budhabhārgavayoḥ phalam || 55 ||

[12] The precession of the equinox for the year 2025 CE accepted by IAU is approximately −24.71325° (or −24° 42′ 47.7″). This value denotes the angular separation between the *Sāyana* and *Nirayaṇa* zodiacs resulting from the precession of the equinoxes. To convert tropical longitudes (such as those provided by Stellarium) to sidereal longitudes aligned with traditional Indian astronomical systems, this correction is subtracted. The value aligns with the Lahiri *ayanāṃśa* and is consistent with IAU ephemeris-based computations.

Table 6 Comparison of the Nirayaṇa longitudes for the sunrise at Mandi on 30th March, 2025 CE

Planet	Sūryasiddhānta	Stellarium	Error
Moon	352° 17′ 26.52″	353° 25′ 34.3″	−1° 8′ 7.78″
Mercury	336° 8′ 29.04″	335° 23′ 45.3″	0° 44′ 43.74″
Venus	315° 58′ 37.2″	333° 49′ 27.3″	−17° 50′ 50.1″
Sun	345° 17′ 21.84″	344° 57′ 23.3″	0° 19′ 58.54″
Mars	91° 59′ 10.68″	88° 23′ 42.3″	3° 35′ 28.38″
Jupiter	54° 53′ 39.12″	50° 2′ 31.3″	4° 51′ 7.82″
Saturn	322° 55′ 21.72″	329° 33′ 12.3″	−6° 37′ 50.58″

Table 7 Comparison of the Nirayaṇa longitudes for the sunrise at Mandi on 16th August, 2025 CE

Planet	Sūryasiddhānta	Stellarium	Error
Moon	25° 14′ 23.28″	26° 2′ 24.8″	−0° 48′ 1.52″
Mercury	102° 47′ 19.32″	100° 50′ 30.7″	1° 56′ 48.62″
Venus	87° 39′ 23.4″	83° 48′ 58.5″	3° 50′ 24.9″
Sun	118° 39′ 38.16″	118° 42′ 33.7″	−0° 2′ 55.54″
Mars	161° 39′ 14.4″	160° 57′ 40.4″	0° 41′ 34″
Jupiter	84° 32′ 33″	80° 6′ 58.1″	4° 25′ 34.9″
Saturn	328° 22′ 6.24″	336° 17′ 36.7″	−7° 55′ 30.46″

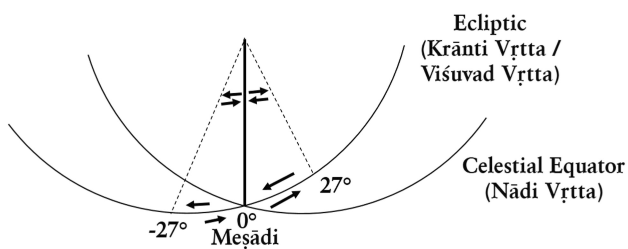


Fig. 9 Precession of the Equinoxes

Table 8 Comparison of the Sāyana longitudes for the sunrise at Mandi on 30th March, 2025 CE

Planet	Sūryasiddhānta	Stellarium	Error
Moon	15° 11′ 8.52″	18° 7′ 8.2″	−2° 55′ 59.68″
Mercury	359° 1′ 48.72″	0° 3′ 21.3″	−1° 1′ 32.58″
Venus	338° 51′ 56.88″	358° 31′ 7.5″	−19° 39′ 10.62″
Sun	8° 10′ 44.76″	9° 33′ 43.1″	−1° 22′ 58.34″
Mars	114° 52′ 32.88″	112° 57′ 57″	1° 54′ 35.88″
Jupiter	77° 47′ 0.96″	74° 40′ 31.9″	3° 6′ 29.06″
Saturn	345° 48′ 43.2″	354° 15′ 6″	−8° 26′ 22.8″

> For the nodes of Mars, Saturn and Jupiter (*kuja-arki-guru-pātānāṃ*), apply the correction like in the case of the *śīghra-phala* correction of the planets. For the nodes of Mercury and Venus (*budha-bhārgavayoḥ*), apply the correction to the third correction (*vāmaṃ tṛtīyakaṃ māndaṃ phalaṃ*) reversely.

Parameśvara's *Sūryasiddhānta Vivaraṇa* commentary explains the meaning of this verse.

> कुजार्किगुरूणां पातेषु स्वं स्वं शीघ्रफलं ग्रहवत्कार्यम् । ग्रहे धनं चेत्तत्पातेऽपि धनं, ऋणं चेदृणम् । शीघ्रफलमत्र चतुर्थकेन्द्रजं गृह्यते । बुधभार्गवयोस्तु पातयोः तृतीयकं, तृतीयकेन्द्रजं, मान्दं फलं वामं, व्यस्तं, कार्यम् । कैश्चिद् अनयोर्मान्दफलं स्वशीघ्रोच्चे व्यस्तं क्रियते । तदपि पातशोधनार्थं बुधभार्गवयोः पातयोरिति कैश्चिन्मन्यन्ते ।
>
> *kujārkigurūṇāṃ pāteṣu svaṃ svaṃ śīghraphalaṃ grahavatkāryam | grahe dhanaṃ cettatpāte'pi dhanaṃ, ṛṇaṃ cedṛṇam | śīghraphalamatra caturthakendrajaṃ gṛhyate | budhabhārgavayostu pātayoḥ tṛtīyakaṃ, tṛtīyakendrajaṃ, māndaṃ phalaṃ vāmaṃ, vyastaṃ, kāryam | kaiścid anayormāndaphalaṃ svaśīghrocce vyastaṃ kriyate | tadapi pātaśodhanārthaṃ budhabhārgavayoḥ pātayoriti kaiścinmanyante |*
>
> For the nodes (*pāteṣu*) of Mars, Saturn and Jupiter (*kuja-arki-gurūṇāṃ*), apply the correction similar to their *śīghra* correction (*svaṃ svaṃ śīghraphalaṃ*). If it was added (*grahe dhanaṃ*), then add the *pāta* correction, or if it was subtracted, then subtract it now (*ṛṇaṃ cedṛṇam*). However, for the nodes of Mercury and Venus (*budha-bhārgavayoḥ*), apply the correction reversely (*vāmaṃ*) to their *manda* correction (*māndaṃ phalaṃ*). Some apply this to *śīghra-phala* correction instead of *manda-phala* correction. Even though, others consider the method described here only for the *pāta* correction of Mercury and Venus.[13]

However, there is no mention of the Moon's *pāta*, because Moon's *pāta* itself is another twin-planet (*yugala-graha*) known as Rāhu-Ketu. As per Chapter 1, the maximum geocentric deviations (*parama vikṣepa*) of the planets are- Moon: 4.5°, Mercury: 2°, Venus: 2°, Mars: 1.5°, Jupiter: 1°, and Saturn: 2°. After converting the same to heliocentric perspective, the maximum heliocentric deviations (*parama vikṣepa*) of the planets are- Moon: 4.9°, Mercury: 7.42°, Venus: 4.74°, Mars: 2.32°, Jupiter: 1.19°, and Saturn: 2.21°.[14]

[13] Thus, Parameśvara in his *Vivaraṇa* commentary to the *Sūryasiddhānta* indicates that even for Mercury and Venus, some apply the *pāta* correction to the *śīghra-phala* correction only. Thus, same procedure of *pāta* correction can be applied for all the planets.

[14] IAU accepted values- Moon: ±5.145°, Mercury: ±7°, Venus: ±3.4°, Mars: ±1.85°, Jupiter: ±1.3°, and Saturn: ±2.5°.

SS 2.56
स्वपातोनाद्ग्रहाज्जीवा शीघ्रात्तु बुधशुक्रयोः ।
विक्षेपघ्नाऽन्त्यकर्णाप्ता विक्षेपस्त्रिज्यया विधोः ॥ 56 ॥

svapātonādgrahājjīvā
śīghrāttu budhaśukrayoḥ |
vikṣepaghnā'ntyakarṇāptā
vikṣepastrijyayā vidhoḥ || 56 ||

For Mars, Jupiter and Saturn, subtract the true position of the node (*spaṣṭapāta*) from their final corrected position, and for Mercury and Venus, subtract the true position of the node (*spaṣṭapāta*) from their *śīghrocca*. From this determine the Rsine value (*bhujajyā* or *jīva sādhana*) [with *śīghra-karṇa* as the hypotenuse]. Multiplying this Rsine value (*jīva*) by *parama-vikṣepa* (*vikṣepaghnā*) and dividing it by the last hypotenuse (*antyakarṇāptā* or *śīghra-karṇāptā*), we obtain the corrected deflection in *kalās* (*spaṣṭa-vikṣepa*) [the latitude (*śara* or *vikṣepa*) suitable for computing the corrected declination (*krānti-saṃskāra-yogya śara*) of a planet.] For the Moon, divide the product by the radius only (*trijyayā vidhoḥ*).

Parameśvara's *Sūryasiddhānta Vivaraṇa* commentary explains the meaning of this verse.

कुजगुरुमन्दानां चतुर्थस्फुटात्स्फुटीकृतं स्वपातं विशोध्य भुजज्यामानयेत् । बुधशुक्रयोस्तु स्वशीघ्रोच्चात्स्वपातं विशोध्य भुजज्यामानयेत् । सा जीवा परमविक्षेपघ्नाऽन्त्यकर्णाप्ता चतुर्थस्फुटसिद्धकर्णाप्ता विक्षेपो भवति । त्रिज्यया विधोः । विधोस्तु पातोनात्स्वात् स्फुटाज्ज्या परमविक्षेपघ्ना त्रिज्यया विभक्ता विक्षेपो भवति ।

kujagurumandānāṃ caturthasphuṭātsphuṭīkṛtaṃ svapātaṃ viśodhya bhujajyāmānayet | budhaśukrayostu svaśīghroccātsvapātaṃ viśodhya bhujajyāmānayet | sā jīvā paramavikṣepaghnā'ntyakarṇāptā caturthasphuṭasiddhakarṇāptā vikṣepo bhavati | trijyayā vidhoḥ | vidhostu pātonātsvāt sphuṭājjyā paramavikṣepaghnā trijyayā vibhaktā vikṣepo bhavati |

For the planets Mars, Jupiter and Saturn, subtract the node (*svapātaṃ viśodhya*) from their fourth corrected position (*caturthasphuṭāt-sphuṭīkṛtaṃ*), and compute the base Rsine value (*bhujajyā*). For the planets Mercury and Venus, subtract the node from their *śīghrocca* (*svaśīghroccāt svapātaṃ viśodhya*) and compute the base Rsine value (*bhujajyā*). Multiplying this Rsine value (*sa jīva*) by the *parama-vikṣepa* (or *parama-śara*) value (*paramavikṣepaghnā*) and dividing it by the last hypotenuse (*antyakarṇāptā* or *śīghra-karṇa*), the hypotenuse obtained from the fourth correction (*caturtha-sphuṭa-siddha karṇāptā*), we obtain the corrected latitude (*vikṣepa*). For Moon use the radius only (*trijyayā vidhoḥ*). However, in the case of Moon (*vidhostu*), obtain the *bhujajyā* from the difference between the corrected Moon and the *pāta* (*pātonāt svāt sphuṭāt*), multiply the *jyā* with the maximum deflection (*parama-vikṣepa-ghnā*), and divide the product by the radius (*trijyayā vibhaktā*) to obtain the instantaneous deflection or latitude (*vikṣepa*).

In the first chapter of the *Sūryasiddhānta*, Verses 41 to 44 (SS 1.41–44) describe the motion of the *pāta* (ascending or descending nodes) of the five planets. It is stated that in one day of Lord Brahmā (*kalpa*), the leftward (*vāmagati*) revolutions of the *pāta* for Mars is 214, for Mercury 488, for Jupiter 174, for Venus 903, and for Saturn 662—all moving in the opposite direction (towards the left, *vāmataḥ*). For the Moon, the number of such leftward revolutions is given as 232,234. This nodal motion is attributed to a twin celestial entity known as Rāhu–Ketu, who move in the zodiac like the *nakṣatras* (lunar constellations), yet advance ahead of them (Ref. Table 9). Rāhu's counterpart, Ketu, is always situated at a distance of 180° from Rāhu, in the same orbital path, and travels with identical motion.

Thus, the term *pāta* in this context refers to the retrograde (or inverse) motion of the node—i.e., westward—in contrast to the eastward mean motion of the planetary bodies. This *vāma* (leftward) movement of the node is fundamental to the computation of planetary latitudes and eclipses in traditional Indian astronomy.

For a given *ahargaṇa* (A), the longitude of the node (θ_{pa}) of a planet is calculated using the number of leftward revolutions of the node per *kalpa* (a day of Brahmā). The general formula is:

$$Rev_{pa} = \frac{P\bar{a}ta\ in\ a\ kalpa}{No\ of\ days\ in\ a\ kalpa} \times ahargaṇa,$$

$$\theta_{pa} = (Rev_{pa})_{remainder} \times 360°.$$

This verse tells us to adjust the true longitude of the planet (θ) by aligning it with its *pāta* (i.e., the longitude of the ascending

Table 9 Number of Pāta revolutions of the planets

Planet	Pāta in a Kalpa	Caturyugas for Pāta revolution
Mercury	488	2.049180328
Venus	903	1.107419712
Mars	214	4.672897196
Jupiter	174	5.747126437
Saturn	662	1.510574018
Moon (Rāhu–Ketu)	232,234,000	6794.3998 Days (18.6016 Years)

node of its orbit, θ_{pa}). This is done to properly project the planet's position off the ecliptic plane. The corrected longitude (used for latitude calculations) is derived by:

$$\Delta\theta = \theta - \theta_{pa}.$$

This difference is essentially the argument of latitude, relative to the orbital plane. Once the difference in longitudes is found, the celestial latitude (*vikṣepa* or *śara*) is computed using,

$$\acute{S}ara = maximum\ inclination\ (i) \times \sin(\Delta\theta),$$

where maximum inclination (i) is the maximum tilt of the orbital plane (*parama-vikṣepa*), and the sine of the angular difference gives the approximate instantaneous deflection of the planet from the ecliptic. However, referring to the spherical trigonometry (Ref. Fig. 10) the same is expressed as,

$$\sin(Vik\d{s}epa) = \sin(i) \times \sin(\Delta\theta)$$

when approximated for smaller angels,

$$Vik\d{s}epa = \quad i \times \sin(\Delta\theta).$$

This value represents the angular height above or below the ecliptic—the latitude (β). The text here describes the personalized procedure of *pāta* correction (*pāta-saṃskāra*) for computing the *Vikṣepa*. In the case of Mars, Saturn and Jupiter, the *pāta* correction should be added or subtracted to the fourth corrected value (*śeṣa-śīghra-phalam*). However, in the case of Mercury and Venus, it should be added or subtracted to the third corrected value (*śeṣa-manda-phalam*) opposite to the third correction. And compute the base Rsine value (*bhujajyā*).

Bhujajyā of Kuja-arki-guru-candra:

$$= R\sin(\theta_{spa\d{s}\d{t}agraha} - \theta_{pa}),$$

Bhujajyā of Budha-śukra:

$$= R\sin(\theta_{\acute{s}\bar{\imath}ghrocca} - \theta_{pa}).$$

The text further says—Multiplying the Rsine value (*bhujajyā* or *jīva*) obtained from the above *pāta* corrected value, by *parama-vikṣepa* or *parama-śara* and dividing it by the last hypotenuse (*antyakarṇa* or *śīghra-karṇa*) is known as the corrected deflection in *kalās* (*spaṣṭa-vikṣepa*), which is suitable to obtain the corrected declination of the planet (*krānti-saṃskāra yogya-śara*).

$$Vik\d{s}epa = \frac{Bhujajy\bar{a} \times Parama\text{-}vik\d{s}epa}{Antyakar\d{n}a}.$$

The text further says—For the Moon, divide the product by the radius (*trijyā*) only.

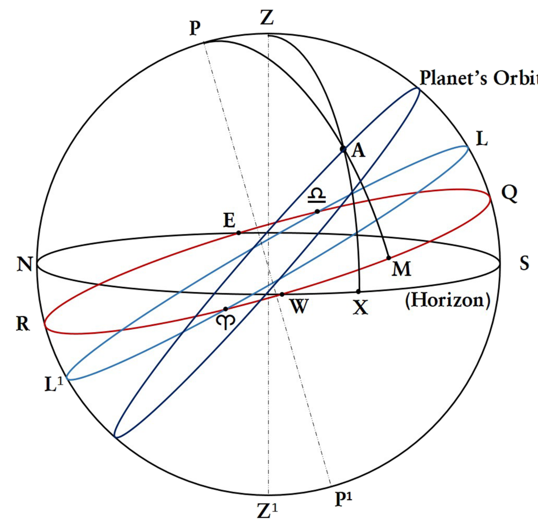


Fig. 10 The annual drift of the plane of the orbit from the Ecliptic

$$Vik\d{s}epa = \frac{Bhujajy\bar{a} \times Parama\text{-}vik\d{s}epa}{Trijy\bar{a}}$$

when approximated, the above two formulas become,

$$Vik\d{s}epa\ or\ \acute{S}ara = i \times \sin(\Delta\theta).$$

SS 2.57
विक्षेपापक्रमैकत्वे क्रान्तिर्विक्षेपसंयुता ।
दिग्भेदे वियुता स्पष्टा भास्करस्य यथाऽगता ॥ 57 ॥

vikṣepāpakramaikatve
krāntirvikṣepasaṃyutā |
digbhede viyutā spaṣṭā
bhāskarasya yathā'gatā || 57 ||

When the deflection (*vikṣepa*) and declination (*krānti*) are in the same direction, add the deflection to the mean declination and when the deflection and the declination are in the opposite directions, subtract the deflection from the mean declination, to obtain the true declination (*spaṣṭakrānti*). For the Sun, the mean declination (*madhyakrānti*) is the true declination.[15]

The mean declination (*madhya-krānti*) of the planet is determined based on the X, Y, and Z coordinates of the position of the planet on the Zodiac (*krānti-vṛtta*). Here, the X, Y, and Z coordinates are the coordinates of the full-*śīghra* corrected position of the planets in the cases of Mars, Mercury, Jupiter, Venus, and Saturn, and they are of the full-*manda* corrected position in the case of Moon.

[15] Traveling in the declination circle (*krānti-vṛtta*), the Sun does not deflect and create a latitude (*vikṣepa*).

$$Madhya\text{-}kr\bar{a}nti\ (\delta_m) = \sin^{-1}\left(\frac{Z}{\sqrt{X^2+Y^2+Z^2}}\right).$$

Or, the same (δ_m) can also be determined for a given planet's ecliptic longitude (λ) and the obliquity of the ecliptic (ϵ, which is 24° as per *Sūryasiddhānta*):

$$\delta_m = \sin^{-1}\left(\frac{Antyakarṇa \times \sin(\lambda) \times \sin(\epsilon)}{Antyakarṇa}\right)$$
$$= \sin^{-1}(\sin(\lambda) \times \sin(\epsilon)).$$

Then the true declination (*spaṣṭa-krānti*) of the planet is defined as,

$$Spaṣṭakrānti = Madhyakrānti \pm Vikṣepa,$$
$$\delta = \delta_m \pm \beta.$$

Since, the difference between *vikṣepa* (YA) and *śara* (β, MA) is very much negligent in the case of planets due to their smaller orbital inclinations, they are interchangeably used. Thus the above formula is used to determine the *Spaṣṭakrānti* of the planets.

However, alternately to find the true declination of the planet (angle from the celestial equator), *Sūryasiddhānta* uses the result from verse 56 and transforms it into declination (δ) referring to the spherical trig (Refer to the spherical triangle AKP from the Fig. 11), using a projection through the obliquity of the ecliptic (ϵ):

$$\cos(a) = \cos(b) \times \cos(c) + \sin(b) \times \sin(c) \times \cos(A),$$
$$\cos(90-\delta) = \cos(90-\beta) \times \cos(\epsilon) + \sin(90-\beta) \times \sin(\epsilon) \times \cos(90-\lambda),$$
$$\sin(\delta) = \sin(\beta) \times \cos(\epsilon) + \cos(\beta) \times \sin(\epsilon) \times \sin(\lambda),$$

where:

λ: ecliptic longitude of the planet w.r.t. the node,

ϵ: obliquity of the ecliptic (SS: 24°, IAU: 23.5°).

This procedure of determining *spaṣṭa-krānti* is for all planets except for the Sun. Since, the Sun travels on the declination circle (*krānti-vṛtta*) only, and hence there is no correction required because of the absence of deflection or latitude (*vikṣepābhāvāt*). This is an approximate procedure for the determination of the true declination (*spaṣṭa-krānti*) and the true latitude (*spaṣṭa-vikṣepa* or *spaṣṭa-śara*) of the planet (known as *Śarānayanam*).

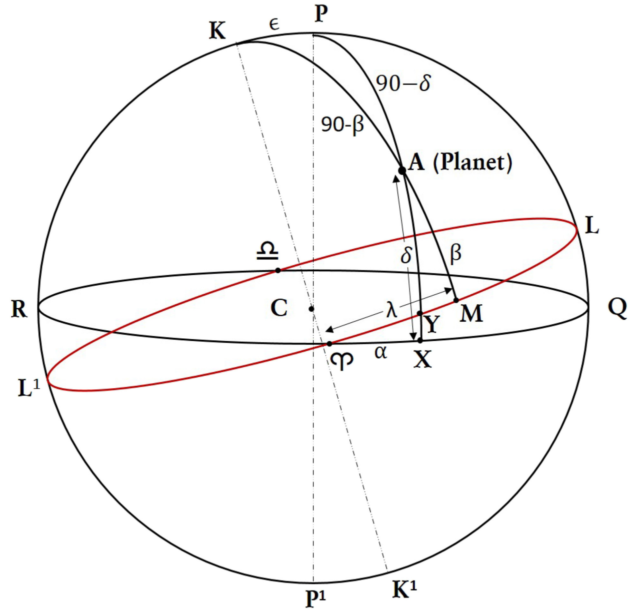


Fig. 11 Determination of the True Declination of the Planet. The angle of the arc 'AX' (δ) is the true declination (*spaṣṭa-krānti*), the angle of the arc 'XY' is the mean declination (*madhya-krānti*), the angle of the arc 'AY' is the deflection of the planet from ecliptic (*vikṣepa*), and the angle of the arc 'AM' (β) is the latitude (*śara*) of the planet w.r.t. the ecliptic

6.1 Geocentric latitude and heliocentric latitude

Thus, having computed the geocentric latitude and the Declination of the planets, and then to convert a planet's geocentric ecliptic latitude (β_g) into its heliocentric ecliptic latitude (β_h), we need to understand that the two coordinate systems are centered at different locations.

The Geocentric coordinates are Earth-centered (as per the observer on Earth) and the Heliocentric coordinates are Sun-centered (planet's position with respect to the Sun). The simplified formula for the same is given in *Tantrasangraha* by Nīlakaṇṭha Somayājī, translated and annotated by Ramasubramanian and Sriram (2011) and Ramasubramanian and Sriram (2003). The geocentric latitude at any desired instant (*iṣṭa-vikṣepa*) can be expressed as,

$$\beta_E = \beta_{max} \times \frac{R\sin(\Delta\theta)}{Antyakarṇa}.$$

From Fig. 12, 'P' and 'N' refer to the planet and the node, and 'S' is the mean Sun. The orbit of the planet is inclined at an angle 'i' with respect to the mean Sun. Then the heliocentric latitude β_h is given as below assuming the latitude and the inclination to be small.

$$\beta_h = i \times \sin(\Delta\theta).$$

Now, the relation between the geocentric latitude (β_E), which is measured with respect to the Earth, and β_h is obtained referring to the two Triangles ΔEPM and ΔSPM from Fig. 12.

$$\beta_E \times EP = \beta_h \times SP,$$

$$\beta_E = \beta_h \times \frac{SP}{EP}$$

$$= i \times \sin(\Delta\theta) \times \frac{SP}{EP}.$$

For the three outer planets, SP = R (the mean Radius of the Planet), and EP = the *Antyakarṇa* or *śīghrakarṇa*. Then,

$$\beta_E = \frac{i \times R \times \sin(\Delta\theta)}{Antyakarṇa}.$$

Comparing this with the expression of β_h, the inclination i can be identified with the maximum deflection (β_{max}). For the two inner planets, SP = r_s, the radius of the *śīghra* epicycle. Then,

$$\beta_E = \frac{i \times r_s \times \sin(\Delta\theta)}{Antyakarṇa}$$

$$= \frac{i \times R \times \left(\frac{r_s}{R}\right) \times \sin(\Delta\theta)}{Antyakarṇa}.$$

Again comparing this with the expression of β_h, the product $i \times \left(\frac{r_s}{R}\right)$ can be identified with the maximum deflection (β_{max}) or the inclination of the inner planet's orbit with respect to the ecliptic (i), can be identified as $\beta_{max} \times \left(\frac{R}{r_s}\right)$.

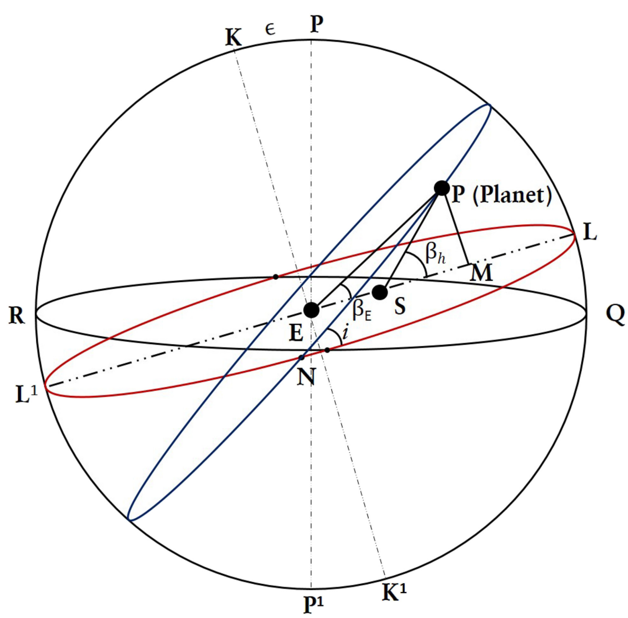


Fig. 12 Interrelation between geocentric latitude and heliocentric latitude of a planet

Table 10 Comparison of the textual values of the inclinations of the planetary orbits with IAU

Planet	Maximum deflection (β_{max})	Corresponding inclination (i)	IAU inclination
Moon	4° 30′	4° 54′	± 5.145°
Mercury	2°	5° 24.8′	7°
Venus	2°	2° 44.9′	3° 24′
Mars	1° 30′	1° 30′	1° 51′
Jupiter	1°	1°	1° 18′
Saturn	2°	2°	2° 29′

The corresponding β_{max} and inclinations (i) are computed and compared with the IAU accepted values in Table 10.

The Table indicates a reasonable concordance between the stated and IAU values for the outer planets. In contrast, the agreement is notably poorer for the inner planets, even after incorporating the correction factor $\frac{R}{r_s}$. This discrepancy may be attributed to the inherent observational challenges in accurately determining the latitudes of the inner planets.

6.2 Parallax correction to lunar latitude

Due to the Moon's proximity, horizontal parallax must be considered. This causes a shift in apparent position relative to an observer on the Earth versus the Earth's center. The *Sūryasiddhānta* treats this via a trigonometric adjustment of the Moon's position based on observer location.

$$Horizontal\ parallax\ (\delta) = \sin^{-1}\left(\frac{R_{Earth}}{D_{Earth-Moon}}\right)$$

$$= \sin^{-1}\left(\frac{1}{60}\right) = 0.955°.$$

This is the maximum parallax in arc degrees when the Moon is on the horizon. Since the Moon's latitude is inclined to the ecliptic, the parallax in latitude depends on the cosine of the latitude:

$$\Delta\beta_{paralax} = -\,\delta \times \cos(\beta),$$

$$\beta_{corrected} = \beta \pm \Delta\beta_{paralax},$$

where R is Earth's radius, D is the distance to the Moon (which is equal to 60 Earth radii, approximate mean value used in ancient Indian astronomy), β is the ecliptic latitude before correction, and $\beta_{corrected}$ is the latitude after correction.[16]

[16] Indian astronomy computes this through tabulated parallax factors and empirical rules, not through spherical trig.

Table 11 Comparison of the *Sāyana* latitudes of *Sūryasiddhānta* against Stellarium for the sunrise at Mandi on 30th March, 2025 CE

Planet	Mean	Pāta	Difference	Sūryasiddhānta	Stellarium	Error
Moon	15.1857	1.1733	14.0124	1° 11′ 6.36″	0° 58′ 57.6″	0° 12′ 8.76″
Mercury	359.0302	43.5608	315.4694	2° 43′ 43.68″	2° 7′ 3.1″	0° 36′ 40.58″
Venus	338.8658	82.5336	256.3322	1° 22′ 50.88″	7° 34′ 11.1″	−6° 11′ 20.22″
Mars	114.8758	62.9379	51.9379	1° 49′ 35.04″	2° 42′ 48.1″	−0° 53′ 13.06″
Jupiter	77.7836	102.555	335.2286	−0° 29′ 54.96″	−0° 18′ 45.8″	−0° 11′ 9.16″
Saturn	345.812	123.2265	222.5855	−1° 29′ 43.08″	−1° 56′ 0″	0° 26′ 16.92″

Table 12 Comparison of the Geocentric *Sāyana* Declinations of *Sūryasiddhānta* with Stellarium for the sunrise at Mandi on 30th March, 2025 CE

Planet	Latitude (śara)	Mean declination (madhyakrānti)	Sūryasiddhānta declination	Stellarium declination	Error
Moon	1.1851	6.1161	7° 18′ 4.32″	8° 0′ 32.2″	− 0° 42′ 27.88″
Mercury	2.7288	− 0.3944	2° 20′ 3.84″	1° 57′ 54.8″	0° 22′ 9.04″
Venus	1.3808	− 8.4328	− 7° 3′ 7.2″	6° 21′ 15″	− 13° 24′ 22.2″
Sun	0	3.3173	3° 19′ 2.28″	3° 47′ 11.1″	− 0° 28′ 8.82″
Mars	1.8264	21.654	23° 28′ 49.44″	24° 9′ 30.8″	− 0° 40′ 41.36″
Jupiter	− 0.4986	23.4236	22° 55′ 30″	22° 21′ 27.6″	0° 34′ 2.4″
Saturn	− 1.4953	− 5.7215	− 7° 13′ 0.48″	− 4° 3′ 29.7″	− 3° 9′ 30.78″

Table 13 Comparison of the *Sāyana* latitudes of *Sūryasiddhānta* against Stellarium for the sunrise at Mandi on 20th July, 2025 CE

Planet	Mean	Pāta	Difference	Sūryasiddhānta	Stellarium	Error
Moon	53.0865	355.2439	57.8426	4° 8′ 48.48″	4° 19′ 53.2″	−0° 11′ 4.72″
Mercury	129.1798	43.5654	85.6144	−4° 8′ 15″	−3° 36′ 6.4″	−0° 32′ 8.6″
Venus	79.0197	82.5381	356.4816	−4° 52′ 36.48″	−2° 4′ 7.6″	−2° 48′ 28.88″
Mars	168.4306	62.9425	105.4881	2° 14′ 8.52″	0° 45′ 51.8″	1° 28′ 16.72″
Jupiter	101.4348	102.5596	358.8752	−0° 1′ 24.24″	−0° 6′ 0″	0° 4′ 35.76″
Saturn	352.6662	123.2311	229.4351	−1° 40′ 43.32″	−2° 19′ 21.4″	0° 38′ 38.08″

6.3 A case study for the examination

Using the procedure outlined above, the planetary latitudes and declinations were computed and subsequently compared with the *Sāyana* (tropical) latitudes obtained from Stellarium.[17] These Stellarium-derived latitudes and declinations were compared with the *Sāyana* latitudes and declinations produced by the mathematical model for the same date and location (for the sunrise at Mandi on 30th March, 2025 CE). The comparative results, along with the associated errors, are presented in Tables 11 and 12.

As evident from Table 11, the computed latitudes for all planets—except Venus—are in close agreement with those provided by Stellarium. The minor discrepancies observed may be attributed to approximations involved in converting from the geocentric to the heliocentric frame of reference. However, the deviation in Venus's latitude is significantly larger than anticipated, indicating the need for further improvement of the computational algorithm used in the mathematical model.

Likewise, Table 12 shows that the computed mean and True Declination of all planets—except Jupiter and Saturn—closely match the values given by Stellarium. The minor discrepancies observed can likely be attributed to the approximation made in directly adding the latitude (*śara*) to the mean declination (*madhyakrānti*), as prescribed in

[17] The ecliptic latitude values, regarded as *Sāyana* latitudes, are sourced from Stellarium software (https://stellarium-web.org/) with a IAU accepted precession of the equinox value of −24.71325° for the year 2025 CE, recorded at sunrise on March 30 at Mandi.

Sūryasiddhānta (verse SS 2.57). However, the notably larger deviations in the declinations of Jupiter and Saturn may stem from computational approximations, highlighting the need for further improvement of the current mathematical model.

Similarly, the planetary latitudes and declinations were computed and subsequently compared with the *Sāyana* (tropical) latitudes and declinations of Stellarium for two more dates. The comparative results along with the associated errors for the sunrise at Mandi on 20th July, 2025 CE, are presented in Tables 13 and 14.

Similarly, the comparative results along with the associated errors for the sunrise at Mandi on 16th August, 2025 CE, are presented in Tables 15 and 16.

Similarly, here is another example of computation from the text known as "*Grahalāghavam* of *Gaṇeśa Daivajña*," which is translated by Balachandra and Uma (2006). The example provided in the text corresponds to the sunrise of the *śaka* 1534, *Vaiśākha-śukla-pūrṇimā*, which is 16th May, 1612 CE, Tuesday (*ahargaṇa*: 714,404,018,127 Civil days and 6 h). Also, Shylaja and Shubha (2023) and Tejas, Shubha and Shylaja (2020) provide an example of the conjunction of Mars and Saturn around the same time, for the year *śaka* 1532, *Vaiśākha-śukla-caturthī*. These computed values of the five star-planets are compared with those of the *Sūryasiddhānta*, and the comparative results along with the associated errors for the given day are presented in Table 17.

Observing the above three set of results, from Tables 11 to 17, the computed mean and True Declination and latitudes of some of the planets are closely matching with the values given by Stellarium. The minor discrepancies observed can likely be attributed to the approximation made in directly adding the latitude (*śara*) to the mean declination (*madhyakrānti*) as per Verse SS 2.57. Especially, in Table 17, which compares with *Grahalāghavam*, except for Mercury, all other parameters are

Table 14 Comparison of the Geocentric *Sāyana* Declinations of *Sūryasiddhānta* with Stellarium for the sunrise at Mandi on 20th July, 2025 CE

Planet	Latitude (śara)	Mean declination (madhyakrānti)	Sūryasiddhānta declination	Stellarium declination	Error
Moon	4.1468	18.9779	23° 7′ 28.92″	23° 4′ 33.3″	0° 2′ 55.62″
Mercury	− 4.1375	18.3783	14° 14′ 26.88″	12° 45′ 39.6″	1° 28′ 47.28″
Venus	− 4.8768	23.5338	18° 39′ 25.2″	20° 45′ 54.3″	−2° 6′ 29.1″
Sun	0	21.4815	21° 28′ 53.4″	20° 38′ 39.3″	0° 50′ 14.1″
Mars	2.2357	4.679	6° 54′ 52.92″	5° 3′ 15.1″	1° 51′ 37.82″
Jupiter	− 0.0234	23.4946	23° 28′ 16.68″	23° 1′ 34.6″	0° 26′ 42.08″
Saturn	− 1.6787	− 2.9761	−4° 39′ 17.28″	−1° 22′ 39.4″	−3° 16′ 37.88″

Table 15 Comparison of the *Sāyana* latitudes of *Sūryasiddhānta* against Stellarium for the sunrise at Mandi on 16th August, 2025 CE

Planet	Mean	Pāta	Difference	Sūryasiddhānta	Stellarium	Error
Moon	48.1428	353.8145	54.3283	3° 58′ 44.4″	4° 29′ 31.8″	−0° 30′ 47.4″
Mercury	125.7344	43.5665	82.1679	−0° 56′ 12.12″	−1° 48′ 46.7″	0° 52′ 34.58″
Venus	153.0881	82.5392	70.5489	−2° 5′ 56.76″	0° 43′ 13.8″	−1° 22′ 43″
Mars	184.5494	62.9436	121.6058	1° 58′ 32.52″	0° 26′ 5.3°	1° 32′ 27.22″
Jupiter	107.4376	102.5607	4.8769	0° 6′ 4.32″	−0° 3′ 29.5″	0° 9′ 33.82″
Saturn	351.2634	123.2322	228.0312	−1° 38′ 34.8″	−2° 25′ 55.1″	−0° 47′ 20.3″

Table 16 Comparison of the Geocentric *Sāyana* Declinations of *Sūryasiddhānta* with Stellarium for the sunrise at Mandi on 16th August, 2025 CE

Planet	Latitude (śara)	Mean declination (madhyakrānti)	Sūryasiddhānta declination	Stellarium declination	Error
Moon	3.979	17.6344	21° 36′ 47.88″	22° 16′ 9.6″	−0° 39′ 21.72″
Mercury	− 0.9367	19.2912	18° 21′ 16.2″	17° 7′ 20.8″	1° 13′ 55.4″
Venus	− 2.0991	22.3863	20° 17′ 13.92″	21° 26′ 35″	−1° 9′ 21.08″
Sun	0	14.6485	14° 38′ 54.6″	13° 42′ 39.2″	0° 56′ 15.4°
Mars	1.9757	− 1.8488	0° 7′ 37.2″	−1° 51′ 17.2″	1° 58′ 54.4″
Jupiter	0.1012	22.8329	22° 56′ 2.4″	22° 33′ 20.9″	0° 22′ 41.5″
Saturn	− 1.643	− 3.542	−5° 11′ 6″	−5° 49′ 51.2″	0° 38′ 45.2″

Table 17 Comparison of the Geocentric Sāyana Declinations of Sūryasiddhānta with Grahalāghavam for the sunrise of *śaka* 1534, *Vaiśākha-śukla-pūrṇimā*

Planet	*Sūryasiddhānta*				*Grahalāghavam*				Error (krānti)
	True longitude	Mean declination	Latitude (śara)	Declination (krānti)	True longitude	Mean declination	Latitude (śara)	Declination (krānti)	
Mercury	48° 53′ 44″	21° 44′ 22″	4° 27′ 36″	26° 11′ 59″	47° 4′ 0″	21° 32′ 31″	1° 43′ 55″	23° 16′ 26″	2° 55′ 33″
Venus	74° 33′ 13″	23° 59′ 38″	2° 24′ 42″	26° 24′ 21″	72° 15′ 46″	23° 58′ 58″	2° 5′ 23″	26° 4′ 21″	0° 20′ 0″
Mars	338° 59′ 28″	−1° 45′ 9″	−2° 1′ 49″	−3° 46′ 58″	335° 56′ 4″	−2° 21′ 34″	−1° 43′ 33″	−4° 5′ 7″	0° 18′ 9″
Jupiter	122° 45′ 41″	15° 19′ 49″	0° 48′ 46″	16° 8′ 35″	122° 9′ 45″	14° 59′ 15″	0° 57′ 54″	15° 57′ 9″	0° 11′ 26″
Saturn	324° 9′ 42″	−6° 39′ 52″	−1° 31′ 46″	−8° 11′ 38″	326° 42′ 30″	−6° 3′ 0″	−1° 34′ 1″	−7° 37′ 1″	−0° 34′ 37″

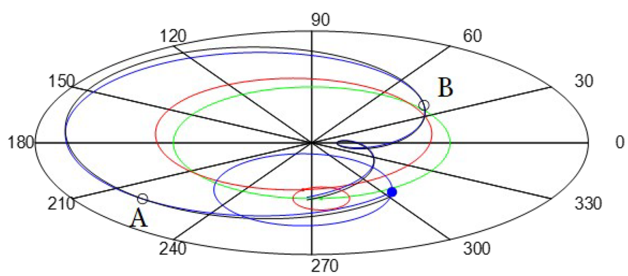


Fig. 13 The *sphuṭa-paridhi* of Mars (blue orbit) vs. the *Pāta* corrected orbit of Mars (black orbit). Wherein, the green and red circles represent the mean and *manda* corrected orbits of Mars respectively

very closely situated. However, the notably larger deviations of the declinations and latitudes of some of the planets, attracts the need for further improvement of the current mathematical model to minimize the differences. More detailed analysis is to be done to arrive at some conclusion and we will be doing it in the next paper and also modify the algorithm to minimize the errors.

Figure 13 depicts the orbital trajectory of Mars over a span of 2 years, along with the corrected path resulting from its

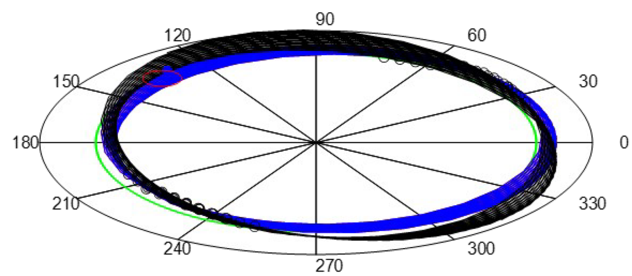


Fig. 15 The Movement of the *pāta* corrected orbit (block circle) of Moon with nodes movement. Wherein, the green and blue circles represent the mean and *manda* corrected orbits of Moon respectively

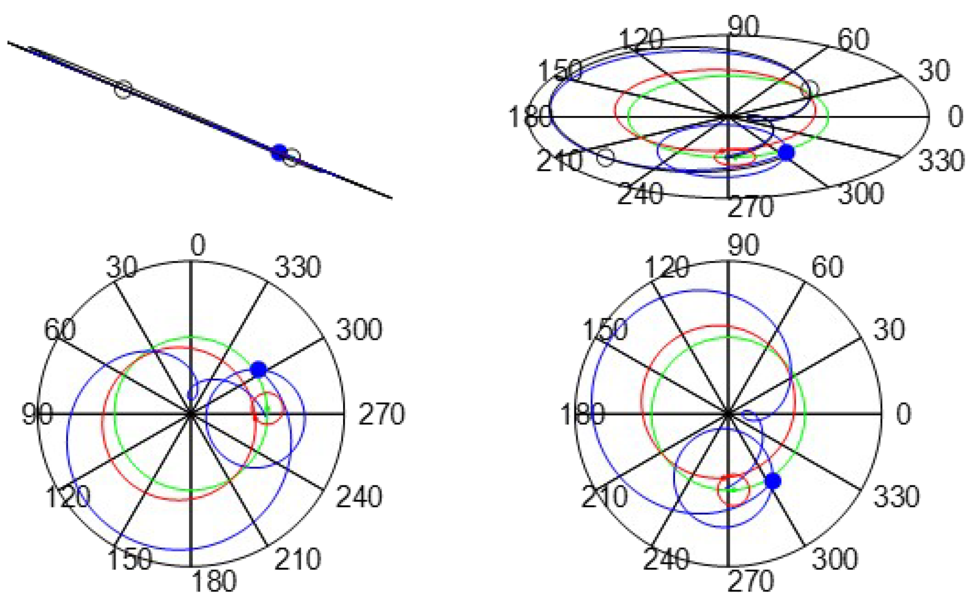


Fig. 14 The distinction between the *sphuṭa-paridhi* of Mars (blue orbit) and the *pāta* corrected orbit of Mars (black orbit)—as seen from the top and as seen from the sides. The *pāta* corrected orbit intersects with the *sphuṭa* orbit at the two nodal points indicated by the two small circles (A and B). Wherein, the green and red circles represent the mean and *manda* corrected orbits of Mars respectively

pāta (orbital inclination). Points 'A' and 'B' mark the ascending and descending nodes of Mars, respectively. The deviation of Mars's annual orbit from the ecliptic plane is distinctly visible in Fig. 14.

Similarly, Fig. 15 illustrates the Moon's orbital path over a two-year period, highlighting the motion of the ascending and descending nodes (*pātas*) in the counter-clockwise direction. The figure also clearly shows the deviation of the Moon's orbital path from the ecliptic due to its *pāta*.

Figure 16 presents the true (i.e., corrected) orbital paths of all the planets within the zodiac, obtained after applying the *śarānayanam* method for computing their latitudes and declinations.

Thus, the planetary (mean, *manda*, and *manda-śīghra* corrected) orbits, including their *pāta*-corrected trajectories, are illustrated in six separate diagrams within Fig. 16. The images clearly indicate that the mean, *manda*, and *manda-śīghra* corrected orbits of all the planets are situated on the inclined ecliptic plane (at an inclination of 24°). Whereas, their *pāta*-corrected trajectories are inclined w.r.t. the ecliptic. This is understood by seeing the small drift between the blue orbit and the black orbit of the respective planet. Based on these drifts, we are computing the declination and latitude of the planets. The *pāta*-corrected orbits of the planets intersect with the ecliptic at both the ascending and descending nodes (indicated by the two small circles in each of the diagram). Eventually these nodal points slowly move in the counter-clockwise direction and come back to the starting point after the predefined time (Refer to Table 9). Only the *pāta* of the Moon completes the circle quickly (around 9 years, Refer to Fig. 15), while others take very long time around few *caturyugas* as indicated in Table 9.

7 Discussion and conclusion

The mathematical model developed from the *Sūryasiddhānta* algorithm facilitates the calculation of planetary geocentric longitudes, latitudes, and declinations for any given time and

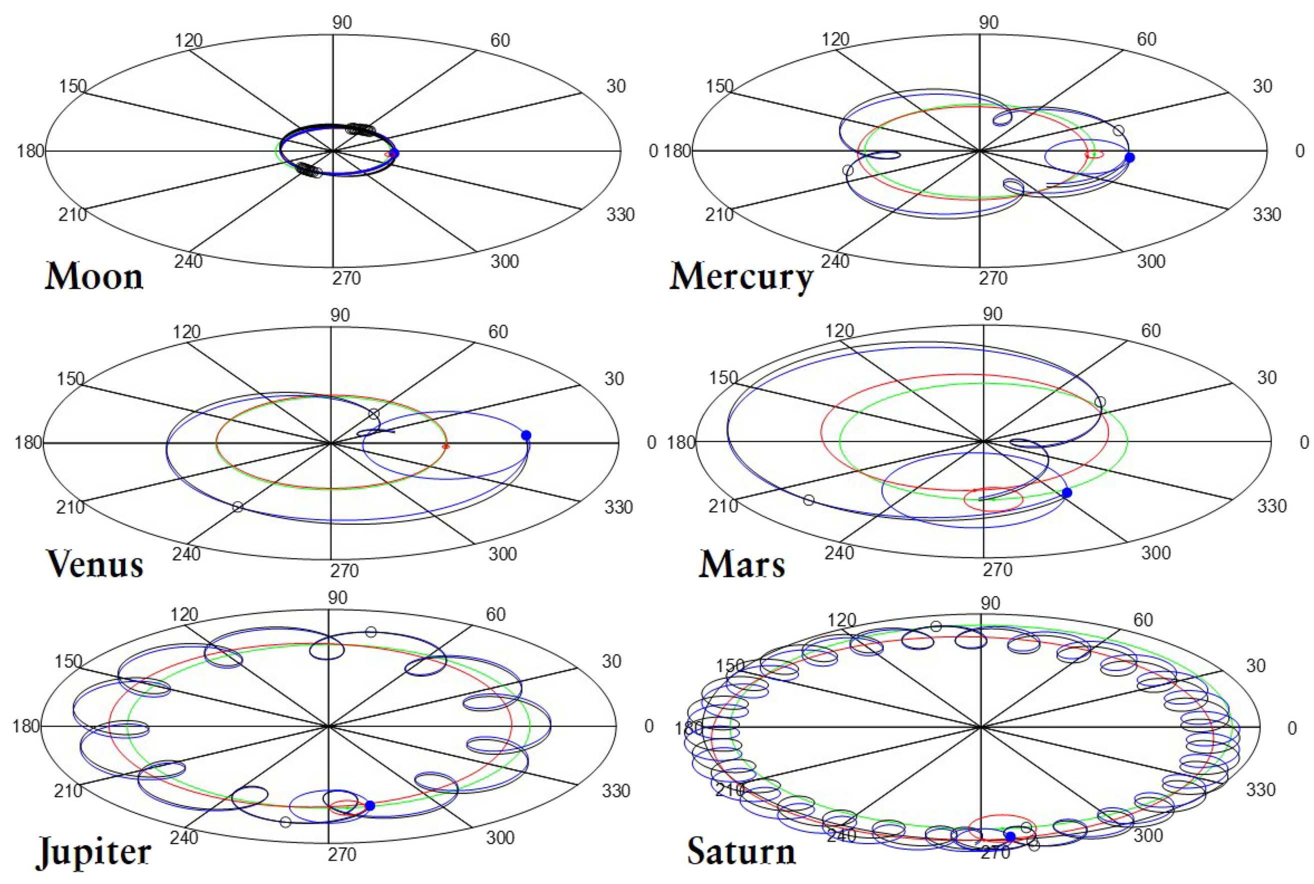


Fig. 16 The trajectory of the true orbits (*sphuṭa-paridhi*, blue orbits) and the *pāta* corrected orbits (black orbits) of the planets (Moon, Mercury, Venus, Mars, Jupiter, and Saturn) depicted w.r.t. the inclined ecliptic plane. Wherein, the green and red orbits represent the mean and *manda* corrected orbits of the respective planets. The first diagram depicts the Moon's orbit, showing the mean orbit along with the *manda*-corrected, and *pāta*-corrected paths. The remaining diagrams present the mean and successively *manda, manda-śīghra*, and *pāta* corrected orbits for each of the other planets (Mercury, Venus, Mars, Jupiter, and Saturn) individually. Wherein the mean, *manda*, and *manda-śīghra* corrected orbits are lying on the inclined ecliptic plane, whereas the *pāta* corrected orbit is inclined w.r.t. ecliptic, intersecting it at the two nodal points indicated by two small circles

geographic location. It also provides a method for converting geocentric parameters into a heliocentric frame of reference. Additionally, the model visually represents planetary orbits over time, enabling a clearer understanding of their motion dynamics and deviations from the ecliptic plane.

As a case study, the model has been employed to determine the planetary latitudes and declinations for three specific dates in the current year (2025 CE)—namely, the sunrises of March 30, July 20, and August 16—for the location of Mandi, Himachal Pradesh. These calculated values are then compared against the corresponding geocentric data retrieved from Stellarium software. To aid in intuitive understanding, graphical representations of the planetary positions and their orbital paths have been included. Furthermore, the same parameters were evaluated in reference to a historical example cited in the text, namely *Grahalāghavam* by *Gaṇeśa Daivajña*, which pertains to the sunrise on *Vaiśākha-śukla-pūrṇimā* of *śaka* 1534, corresponding to May 16, 1612 CE (Tuesday).

The minor discrepancies observed—discussed earlier—are likely due to inherent computational approximations in the *Sūryasiddhānta* algorithm or indicate the need for refining the current model. Historically, Indian astronomers addressed such inconsistencies by incorporating empirical corrections (such as *bīja* corrections) based on repeated observations, thereby improving alignment between theoretical predictions and actual planetary positions (as per the observations). This suggests the importance of refining astronomical parameters and updating the computational model time to time to enhance the accuracy of predicted planetary positions.

Accordingly, the future direction of our work involves examining the nature of these traditional corrections across extended time scales—ranging from years and decades to centuries and *yugas*—with the aim of updating and enhancing the *Sūryasiddhānta*-based computational model. Our objective is to reduce discrepancies and align the results more closely with observational data. The detailed analysis and outcomes of this refinement process will be presented in a subsequent paper.

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Data availability Since, the research work involves only in the mathematical computations, and does not involve in any of the data analysis, there is noneed of any "Data".

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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