Astronomy of the Hindu pañcāṅga: cāndra māna

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PREFACE

The Hindu pañcāṅga is an almanac used by the Hindu community worldwide to regulate the performance of religious rites. Pañcāṅga are published by Hindu religious establishments and are used by Hindu priests to advise lay people. Most Hindus have little understanding of how to read and use the pañcāṅga; we consider it a purely religious document which only priests can comprehend.

Hence, when I talk about the astronomy of the pañcāṅga, I am invariably confronted by blank looks. If I received one rupee for every blank look I have received, I would be a millionaire by now!

The cause for the blank look is twofold. Firstly, as explained above, most people have no understanding of the pañcāṅga, having left its interpretation to priests. Secondly, I am using the word "astronomy" in a context that is considered completely out of place. If the pañcāṅga is a religious document, how can astronomy, which is a science, be connected with it? This leads to the blank look.

Add to this the fact that astronomy itself is a subject alien to the average Indian. Though we take immense pride in the astronomical knowledge of our ancestors, we ourselves have completely abandoned the subject. Though Aryabhata is feted with stamps, and a satellite has been named after him, his astronomical works are not widely read. Astronomy is not taught in schools with any seriousness. Sure, the solar system is part of the middle-school syllabus, but that is the end of it.

Hence, when I take the pañcāṅga, a religious book, and combine it with astronomy, a subject that most people are ignorant of, the result is a look that is the very definition of the word blank!

Yet, this was not always so. Both the pañcāṅga and astronomy were widely understood and used in India from time immemorial up until the beginning of the colonial period.

Consider first the pañcāṅga. Today, we take the Gregorian (Christian) calendar for granted, but if I ask, "Did Krishnadevaraya use the Christian calendar?" you are sure to burst out laughing. This raises the question as to which calendar was in use during the Vijayanagara period. Surely the answer has to be "the Hindu calendar," and the pañcāṅga is nothing but the Hindu calendar! Thus, the pañcāṅga must have been used for civil as well as religious purposes in all Hindu empires, of which Vijayanagara was the last but not the least major one.

If you come to astronomy, the story is even more interesting. Hindu culture is replete with astronomical references. Consider the following:

- The names of stars are routinely used to name people – Ashwini, Rohini, Aditi, Chitra, Swati, Vishak, Anuradha, Shravan, Revati, Arundati are all stars. They are also extremely popular names for people.
- Every Hindu temple has a Navagraha shrine, which devotees reverentially circumambulate nine times. Inside these shrines are representations of seven celestial bodies – Sun (sūrya), Moon (candra), Mars (maṅgala), Mercury (budha), Jupiter (guru), Venus (śukra), Saturn (śani), and the ascending and descending nodes of the Moon (rāhu and kētu, respectively).
- Hindu wedding ceremonies include a tradition of pointing out the stars Arundati and Vashista to the couple, with the officiating priest delivering a homily about the jointness of the double star.
- Bala Krishna reveals his divinity to his foster mother Yashoda by showing her a vision of the entire universe inside his tiny mouth.
- Maheshwara is imagined as Soma-ishwara / Chandra-mouli / Chandra-shekara, the one who wears the Moon in his topknot.

- A colourful legend of the Moon and his twenty-seven wives is a very overt metaphor for the sidereal movement of the Moon across the twenty-seven segments of the ecliptic. This legend also includes a curse that results in the Moon waxing and waning.

Yet, a culture that internalised astronomy to such an extent has now forgotten the science of astronomy. The good news is that the pañcāṅga has survived even though the astronomy has been lost. The time has come to recover that lost science and re-establish the relevance of the Hindu calendar.

This handbook employs the International Alphabet of Sanskrit Transliteration (IAST) for Sanskrit terms. This helps preserve the accuracy of the pronunciation of such terms. Furthermore, Sanskrit nouns are not capitalised, and the customary practice of adding "s" to form plural nouns is not followed.

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CALENDARS AND ASTRONOMY

Most calendars have an astronomical basis.

Consider the modern Gregorian calendar. A year in this calendar is the time taken by the Earth to orbit the Sun once, and that is 365.24 days. Since a quarter day is difficult to handle, this has been rounded off to 365 days and an extra day (leap day) added every four years. This is the astronomical basis of the Gregorian calendar. This makes the Gregorian calendar a solar calendar.

Consider the Islamic calendar. Every time a thin crescent Moon is sighted setting low on the western horizon, following the complete disappearance of the Moon, a new month begins. Twelve such months make a year. This is the astronomical basis of the Islamic calendar. This makes the Islamic calendar a lunar calendar.

The Hindu calendar is more sophisticated in that it combines solar and lunar elements into a single calendar. Both the elements mentioned above are a part of the Hindu calendar—a 365.26–day saura varṣa (solar year), as well as a cāndramāsa (lunar month) that starts immediately after the Moon comes in conjunction with the Sun. In addition, it contains many additional elements such as pakṣa (fortnight), tithi (lunar day), ayana (half year), ṛtu (seasons), etc. Hence, a study of the Hindu calendar results in a deep understanding of the basics of astronomy, specifically the year-round movements of the Sun and the Moon.

HINDU ASTRONOMY

Hindu astronomy traces its roots to the Vedic times. The Vedic corpus navigated the night sky systematically by dividing the zodiac belt into twenty-seven segments, identified by prominent stars (nakṣatra). This understanding of the celestial vault eventually resulted in a rich crop of full-fledged astronomical treatises called *siddhānta*, during the Siddhantic period (post 300 AD).

It is appropriate to explain here why I use the term Hindu astronomy instead of Indian astronomy. The term *Hindu astronomy* refers to a school of astronomy rather than to a religion. This term helps differentiate Hindu astronomical techniques from those of Egyptian, Babylonian, Greek, Islamic, or Chinese astronomers.

The Siddhantic period of Hindu astronomy extended for close to 1500 years (**Plate 1**) and included well-known astronomers such as Aryabhata, Varaha Mihira, Brahmagupta et. al. The Sūrya Siddhanta is a preeminent treatise of this school and serves as the primary source for this handbook.

SŪRYA SIDDHANTA

The Sūrya Siddhanta is a sophisticated astronomical treatise that covers many aspects of geocentric astronomy, such as determining the positions of celestial bodies at any given time, predicting solar and lunar eclipses, predicting the conjunctions of celestial bodies, etc. Its authorship is unknown, and it is estimated to have been composed sometime in the fourth century CE.

Chapters of Sūrya Siddhanta

1	madyama-adhikārah	Mean motion of the planets
2	spaṣta-adhikārah	True places of the planets
3	tri-praśna-adhikārah	Direction, place, and time
4	candra-grahaṇa-adhikārah	Lunar eclipses
5	sūrya-grahaṇa-adhikārah	Solar eclipses
6	chhedyaka-adhikārah	Projection of eclipses
7	grahayutya-adhikārah	Planetary conjunctions
8	bha-grahayutya-adhikārah	Asterisms
9	udaya-asta-adhikārah	Heliacal risings and settings
10	candra-śṛṅgonnatya-adhikārah	Heliacal rising and setting of the Moon
11	pāta-adhikārah	Malignant aspects of the Sun and the Moon
12	bhugola-adhyāyah	Cosmogony and geography
13	jyautiṣa-upaniṣhad-adhyāyah	Armillary sphere and other instruments
14	māna-adhyāyah	Different modes of reckoning time

While astronomy is the main focus of the Surya Siddhanta, we are interested in another aspect, viz., the definition of various calendric elements in the last and final Chapter 14. Needless to say, these calendric elements are defined astronomically.

THE NINE MĀNA OF SŪRYA SIDDHANTA

The Sūrya Siddhanta organises the Hindu calendar into nine groups of calendric elements (the word *māna* indicates one or more calendric elements).

decreasing duration

māna	**calendric elements**
brāhma māna	parārdha, kalpa
prajāpatya māna	manvantara, mahāyuga, yuga, yuga pāda
divya māna	divya varṣa, divya ahorātra
gurormāna	saṃvatsara
saura māna	saura varṣa, ayana, ṛtu, sauramāsa
pitṛya māna	day and night of the ancestors
cāndra māna	cāndra varṣa, cāndramāsa, pakṣa, tithi, karaṇa
sāvana mana	sāvana ahorātra
nākṣatra māna	nākṣatra ahorātra, nāḍi, vināḍi, prāṇa

These groups encompass the concept of time in its entirety, from the exceptionally large (parārdha – 155.52 trillion years) to the relatively small (prāṇa – ~3.989 seconds).

- *brāhma māna* and *prajāpatya māna* deal with exceptionally large timeframes, i.e., epochs.
- *divya māna* recasts a solar year as a day and night (nychthemeron) of the gods and defines a year of the gods as 360 nychthemerons of the gods. This serves as the basis for defining the large timeframes of brāhma māna and prajāpatya māna.
- *gurormāna* defines a year based on the movement of Jupiter.
- *saura māna* defines year, half year, season, and month based on the movement of the Sun.
- *pitṛya māna* recasts lunar fortnights as a day and night on the surface of the Moon!
- *cāndra māna* defines a year, month, fortnight, and day based on the movement of the Moon relative to the Sun.
- *sāvana māna* defines a solar day as the variable period from one sunrise to the next sunrise.
- *nākṣatra māna* defines a day based on the stars. This is the fixed period in which the Earth completes one axial rotation. It then proceeds to subdivide that into the smaller timeframes nāḍi, vināḍi and prāṇa, with prāṇa being the time taken by the Moon to rotate one arc minute on its axis (~3.989 seconds)! nāḍi, vināḍi and prāṇa are analogous (but not equivalent) to hours, minutes, and seconds, respectively.

While a study of all these māna is extremely rewarding, the large timeframes of brāhma mana and prajāpatya māna are not very relevant to us because they never change in our lifetime—we and our descendants will all live in the

first yuga pāda
└-- of kali yuga
└-- of the twenty-eighth mahāyuga
└-- of vaivasvata manvantara
└-- of śveta varāha kalpa
└-- of the dvitīya parārdha of brahma

for many countless more generations to come. It is the four smaller timeframes of saura māna, cāndra māna, sāvana māna and nākṣatra māna that are most relevant to our life and times.

In this handbook, we elaborate on the details of cāndra māna.

THE GEOCENTRIC MODEL

Before we go into the details of cāndra māna, it is necessary to understand one fundamental aspect of Hindu astronomy, namely, its geocentric nature. Hindu astronomy assumes that the Earth is at the centre of the universe, and that all celestial bodies orbit the Earth. Such a geocentric model has been the basis of all ancient astronomy until Copernicus articulated the heliocentric reality.

Since the geocentric model is far removed from the heliocentric reality, what is the point in studying an astronomical treatise based on such an erroneous model? Does it not follow that all the results derived from such a model are bound to be completely wrong?

To answer this question, let us start by studying the heliocentric representation of the solar system given in **Plate 2**. While this picture represents the reality, is it ever possible for any of us to see this view of the solar system? It is not, because this view is an outside-in view; to see this view, one has to exit the solar system! Since we are all trapped on the surface of the Earth, it is impossible for us to see this view, though this indeed represents the reality.

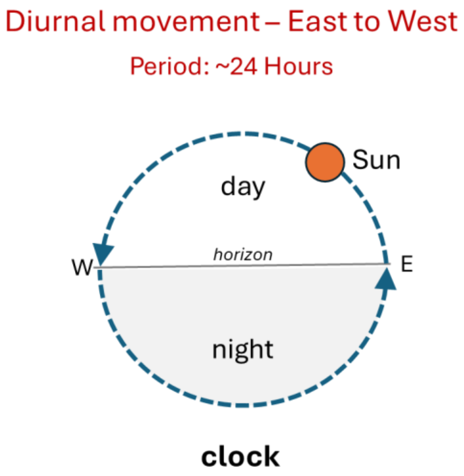
Next follows the natural question, "What is the view that we can indeed see, every night, as we look up at the sky?" This view is represented in **Plate 3**.

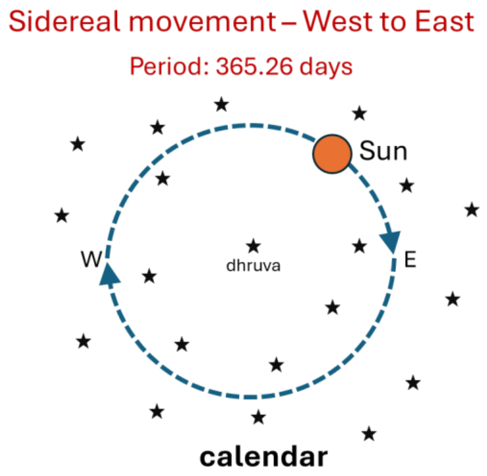
The following points become obvious from this view:

- Only half the solar system will be visible to us at any given time; the other half will be under our feet.
- The orbits of all the planets appear to be close to each other. This is because our human eye is incapable of making sense of astronomical distances. While Jupiter is indeed much farther away than Venus, our eyes are incapable of perceiving this variation in distance.

Plate 3 is a static image and does not capture the movement of the celestial bodies. There are two types of movements of the celestial bodies:

- The movement we easily perceive is the daily rising and setting of the celestial bodies—from east to west—caused by the Earth's axial rotation. This ***diurnal movement****, i.e.,* daily movement, determines the design of clocks.
- There is a second west-to-east movement of the celestial bodies that most of us do not perceive. This second movement is caused by the orbital movement of the celestial bodies (including the Earth) around the Sun. This ***sidereal movement****,* i.e., movement across the fixed stars, determines the design of calendars and is hence the focus of this handbook.





Since we observe the heavens from the surface of a continually moving Earth, the movement of the celestial bodies appears to be rather complex.

Consider first the planets—Mercury, Venus, Mars, Jupiter, and Saturn. They are constantly in motion, orbiting the Sun, and we observe them from the surface of the continuously moving Earth. Hence, the movement of these planets appears to us quite complex:

- While they move from west to east in general (***prograde motion***), occasionally they appear to reverse course and move from east to west (***retrograde motion***).
- Their distance from the Earth varies significantly over time, causing them to vary in brightness when observed from the Earth.

The Moon, of course, orbits our Earth and is straightforward.

Finally, let us consider the Sun. The Sun is stationary and does not move. It is our Earth that orbits the Sun. Yet, due to the limitation of our senses, we are unable to perceive this motion of the Earth. We live our lives in the firm belief that the Earth does not move (if it moves, that is an earthquake). Instead, due to our ever-changing line of sight, it appears to us that the Sun moves from west to east across the stars, as shown in **Plate 4**, and completes one full revolution in 365.26 days.

Thus, the geocentric view is what we actually observe standing on the surface of the Earth. A geocentric model of the solar system attempts to explain the observed movement of celestial bodies accurately. All ancient astronomers—the Egyptians, the Babylonians, the Greeks—constructed and operated with a geocentric model of the solar system. Hindu astronomers were no exception since this is what they observed every night.

The Ahargana Model

At any given time, only half the solar system is visible to us, with the other half being under our feet, below the horizon. To overcome this limitation imposed by physical reality, we use a simulation created using Stellarium, which shows the entire solar system by doing away with the horizon! We refer to this simulation as the *Ahargana Model*.

Stellarium is a modern planetarium software that simulates a view of the sky above any place on Earth at any given time in the past, present or future.

The Ahargana model (**Plate 5**) simulates a geocentric view with the following characteristics:

- It simulates the sky as seen by an observer located in Bengaluru.
- To eliminate clutter, only the apparent orbit of the Sun, known as *the* ***ecliptic,*** is displayed.
- It simulates a wide field-of-view that enables the entire ecliptic to be compressed onto a screen/page.
- The Sun, Moon and the planets are enlarged for better visibility.
- The horizon is removed from the simulation, thus displaying the entire solar system.
- The atmosphere too is removed from the simulation, causing the sky to appear black at all times.
- The observer is facing north, looking towards the pole star (dhruva). Since the latitude of Bengaluru is 13°, the pole star appears 13° above the northern horizon.
- Since the observer is facing north, the direction of prograde motion of the Sun and the Moon will be clockwise in this model.
- The simulation flattens three-dimensional space onto a two-dimensional screen/page. Since the observer is facing north, the area inside the ecliptic represents the space north of the ecliptic, and the area outside the ecliptic represents the space south of the ecliptic. In other words, inside is north; outside is south.

Alternately, in the absence of the horizon, it makes perfect sense to visualise the Earth (and the observer) as being at the centre of the view, with all the celestial bodies orbiting around it. This visualisation is used in the illustrations in Appendix B.

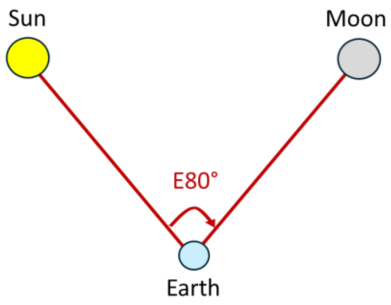
The Ahargana model is not static. By accelerating the passage of time, the Ahargana model compresses the movement of the celestial bodies over long periods of time (such as fortnights, months, and years) into a few minutes, thus helping to visualise and understand calendric concepts. Freeze-frame screenshots of these dynamic simulations are leveraged in this document to illustrate various calendric concepts (Appendix B).

ELONGATION

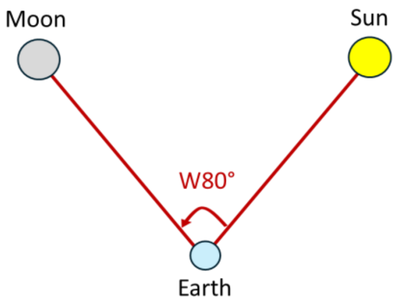
In the geocentric model, distances between celestial bodies are measured in angular measures, as observed from the surface of the Earth, and not in linear measures such as kilometres or light years. As mentioned earlier, our eyes are incapable of making sense of astronomical distances that run into millions of kilometres or light years. We are only capable of assessing how far east/west (**celestial longitude**) and north/south (**celestial latitude**) one celestial body is from another.

Plate 6 shows that guru (Jupiter) is 68° E of śukra (Venus), whereas the linear distance separating them is of the order of 600 million kilometres. In observational astronomy, we are only interested in seeing celestial bodies; unlike ISRO, we have no interest in actually travelling to those planets!

Elongation is the angular distance (celestial longitude) of the Moon or a planet from the Sun, as seen from the surface of the Earth. Elongation is measured east (E) or west (W) of the Sun, whichever is shorter. Hence, elongation is always between 0° (in conjunction with the Sun) and 180° (in opposition to the Sun).



Elongation of the Moon
(East of the Sun)



Elongation of the Moon
(West of the Sun)

CĀNDRA MĀNA

The following is a snapshot of the calendric elements in cāndra māna:

12 months in a year:

1. caitra māsa
2. vaiśākha māsa
3. jyaiṣṭha māsa
4. āṣāḍha māsa
5. śrāvaṇa māsa
6. bhādrapada māsa
7. āśvina māsa
8. kārttika māsa
9. mārgaśīrṣa māsa
10. pauṣa māsa
11. māgha māsa
12. phālguna māsa

2 fortnights in a month:

- śukla pakṣa
- kṛṣṇa pakṣa

15 days in a fortnight:

1. prathama tithi
2. dvitīya tithi
3. tṛtīya tithi
4. caturthī tithi
5. pañcamī tithi
6. ṣaṣṭhī tithi
7. saptamī tithi
8. aṣṭamī tithi
9. navamī tithi
10. daśamī tithi
11. ekādaśī tithi
12. dvādaśī tithi
13. trayodaśī tithi
14. caturdaśī tithi
15. pūrṇimā tithi / amāvāsyā tithi

These calendric elements are all defined based on the movement of the Moon relative to the Sun. Since elongation is the measure of this relative movement, all the above calendric elements are defined in terms of elongation.

AMĀVĀSYĀ AND PŪRṆIMĀ

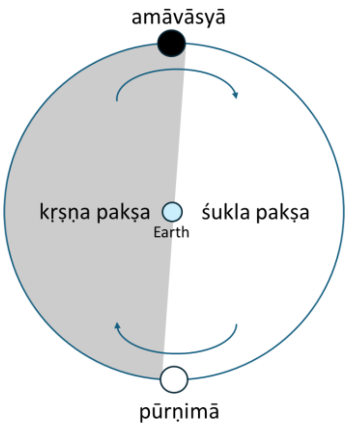
From here onward, we focus our attention on the Moon.

The moment in time when the elongation of the Moon is 0° is known as ***amāvāsyā*** (**Plate 7**). This is nothing but the New Moon, when the Moon is in conjunction with the Sun. The moment in time when the elongation of the Moon is 180° is known as ***pūrṇimā*** (**Plate 8**). This is nothing but the Full Moon, when the Moon is in opposition to the Sun. It is worth highlighting that since both the Sun and the Moon are continually in motion, amāvāsyā and pūrṇimā are moments in time that last a fraction of a second.

These are not to be confused with amāvāsyā tithi and pūrṇimā tithi, which will be explained later.

PAKṢA

From here, we start our discussion of the calendric elements of cāndra māna.



A ***pakṣa*** is a lunar fortnight.

śukla pakṣa is the waxing fortnight. It begins immediately after amāvāsyā and ends with pūrṇimā, i.e., it is the time taken by the Moon to move from amāvāsyā (0° elongation) to pūrṇimā (180° elongation).

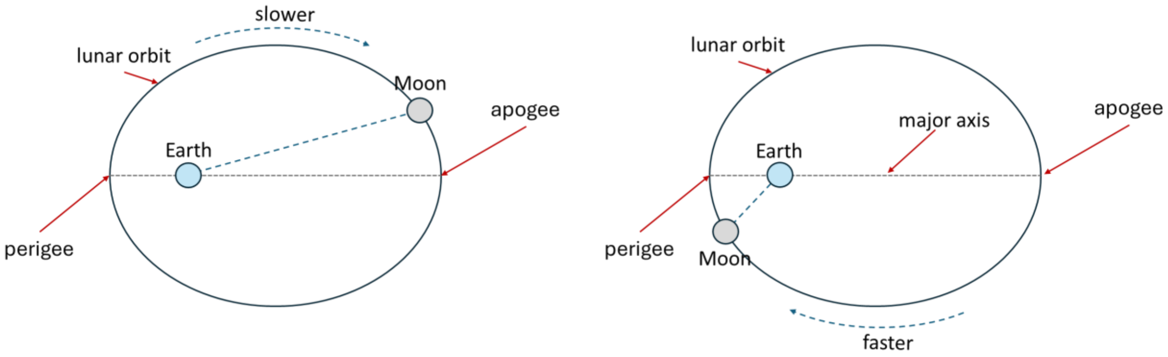
kṛṣṇa pakṣa is the waning fortnight. It begins immediately after pūrṇimā and ends with amāvāsyā, i.e., it is the time taken by the Moon to move from pūrṇimā (180° elongation) to amāvāsyā (0° elongation).

It is worth highlighting that the moment of pūrṇimā is included in śukla pakṣa and marks the end of śukla pakṣa (**Plate 9**). This makes perfect sense since pūrṇimā is the moment when the Moon is full and is logically the culmination of the waxing fortnight. In the same way, the moment of amāvāsyā is included in kṛṣṇa pakṣa and marks the end of kṛṣṇa pakṣa (**Plate 10**). This too makes perfect sense since amāvāsyā is the moment when the Moon is fully dark and is logically the culmination of the waning fortnight.

DURATION OF PAKṢA

The durations of pakṣa vary but average 14.75 days over an entire year. This variation occurs because the orbits of the Sun, the Moon, and the planets are slightly elliptical, and their angular velocities are not constant; sometimes they move slower and sometimes faster. When the Sun and the Moon move from their closest to Earth (perihelion/perigee) to farthest from Earth (aphelion/apogee), they move slower, and vice versa.

It is worth noting that Hindu astronomers accounted for this non-uniform angular velocity in their procedures for calculating the positions of the Sun, the Moon, and the planets. In modern science, these variations are codified by Johannes Kepler's second law of planetary motion.



Note that the above figure exaggerates how elongated the elliptical orbits are. The Ahargana model provides more realistic, near-circular representations in Appendix B.

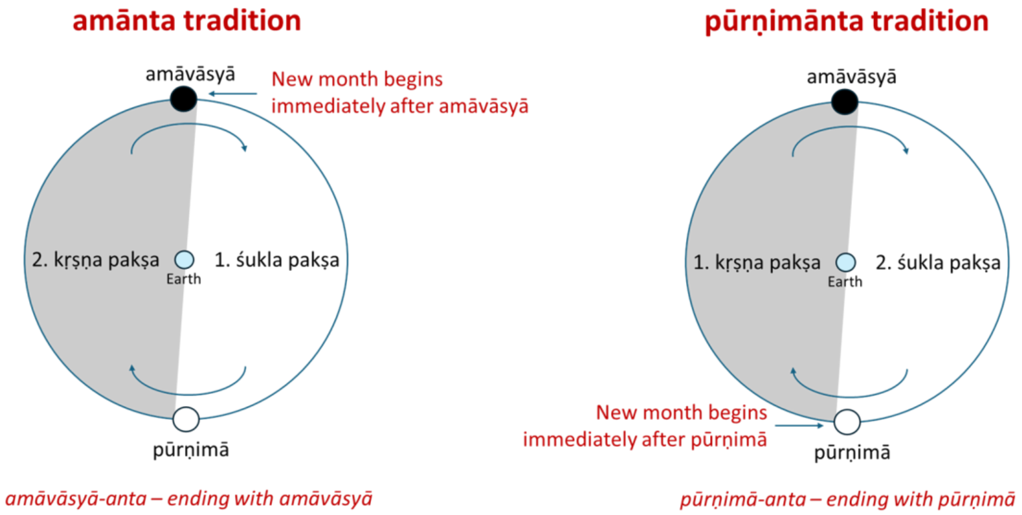
CĀNDRAMĀSA

A ***cāndramāsa*** is a lunar month. It is composed of two consecutive pakṣa.

AMĀNTA AND PŪRṆIMĀNTA VARIATIONS

Two variations of cāndramāsa are in use today.

In one variation, a cāndramāsa is composed of śukla pakṣa followed by kṛṣṇa pakṣa, i.e., a cāndramāsa is the time taken by the Moon to move from one amāvāsyā to the next amāvāsyā. It follows that in this variation, a cāndramāsa will end with amāvāsyā; pūrṇimā will occur in the middle of the month. Hence, this variation is known as the ***amānta*** calendar (for amāvāsyā-anta, i.e., ending with amāvāsyā). This variation is followed predominantly in Southern India.



amānta tradition

pūrṇimānta tradition

amāvāsyā-anta – ending with amāvāsyā

pūrṇimā-anta – ending with pūrṇimā

In the other variation, a cāndramāsa is composed of kṛṣṇa pakṣa followed by śukla pakṣa, i.e., a cāndramāsa is the time taken by the Moon to move from one pūrṇimā to the next pūrṇimā. It follows that in this variation, a cāndramāsa will end with pūrṇimā; amāvāsyā will occur in the middle of the month. Hence, this variation is known as the ***pūrṇimānta*** calendar (for pūrṇimā-anta, i.e., ending with pūrṇimā). This variation is followed predominantly in Northern India.

In practice, the pūrṇimānta calendar is ahead of the amānta calendar by one pakṣa, as shown in **Plate 11**. When a pūrṇimā occurs, followers of the pūrṇimānta calendar flip to the next month; followers of the amānta calendar wait until the occurrence of the next amāvāsyā. It follows that during every śukla pakṣa, the two calendars agree, but during every kṛṣṇa paksha, the pūrṇimānta calendar will be one month ahead of the amānta calendar.

In the rest of this handbook, we assume the amānta calendar.

DURATION OF CĀNDRAMĀSA

The durations of cāndramāsa vary but average 29.5 days over an entire year. This variation comes about because the orbits of the Sun and the Moon are slightly elliptical, and their angular velocities are not constant.

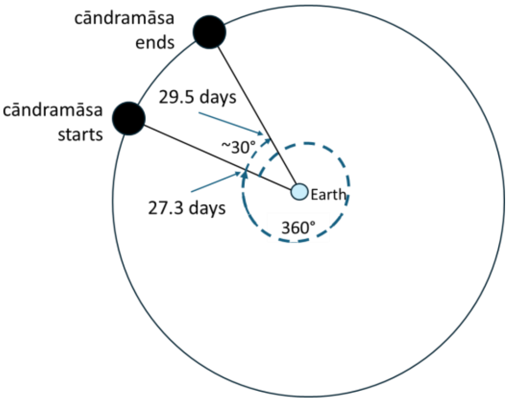
TWO ORBITAL PERIODS OF THE MOON

We have seen that a cāndramāsa is the time taken by the Moon to move from one amāvāsyā to the next amāvāsyā. This may lead you to believe that the Moon completes one orbit around the Earth in a cāndramāsa, but this would be an incomplete understanding.

As the Moon moves around the Earth, the Sun is not standing still. The Sun is also in (apparent) motion around the Earth.

Starting immediately after an amāvāsyā, the moon completes one orbit around the Earth and returns to its starting point in 27.3 days. This is known as the ***sidereal orbit*** of the Moon.

During this time, the Sun has moved forward by ~30°. Hence, the Moon has to move an additional ~30° (in an additional 2.2 days) to be in conjunction with the Sun again, i.e., for the next amāvāsyā to occur. Thus, the Moon moves ~390° during one cāndramāsa! This is known as the ***synodic orbit*** of the Moon.



Thus, one synodic orbit of the Moon is a cāndramāsa. It is interesting to note that the sidereal orbit of the Moon also finds a place in the Hindu calendar. The number 27 makes its appearance in the Hindu calendar as the number of nakṣatra in the nakṣatra maṇḍala! More about this in Appendix A.

Furthermore, the additional 30° that the Moon has to cover to arrive at the next conjunction is the very definition of a rāśi. rāśi is a part of saura māna and is outside the scope of this handbook.

Plate 12 illustrates these concepts.

CĀNDRA VARṢA

A ***cāndra varṣa*** is a lunar year. It is composed of twelve lunar months. Sometimes an additional (thirteenth) month is added for synchronisation with the solar year.

#	cāndramāsa	begins in
1	caitra māsa	March / April
2	vaiśākha māsa	April / May
3	jyaiṣṭha māsa	May / June
4	āṣāḍha māsa	June / July
5	śrāvaṇa māsa	July / August
6	bhādrapada māsa	August / September
7	āśvina māsa	September / October
8	kārttika māsa	October / November
9	mārgaśīrṣa māsa	November / December
10	pauṣa māsa	December / January
11	māgha māsa	January / February
12	phālguna māsa	February / March

The adjoining table shows the names of the twelve cāndramāsa and their correspondence to the months of the Gregorian calendar.

It follows that a cāndra varṣa ends with phālguna amāvāsyā. The lunar New Year—*cāndra māna yugādi*—is celebrated immediately after phālguna amāvāsyā.

DURATION OF CĀNDRA VARṢA

The durations of cāndra varṣa vary slightly but average 354 days (29.5 days x 12) over multiple years. This variation comes about because the orbits of the Sun and Moon are somewhat elliptical, and their angular velocities are not constant.

NUMBERING OF CĀNDRA VARṢA

In the Hindu calendar, years are numbered starting from a historical epoch. Two epochs are in use today, and are mapped to Gregorian calendar years as follows:

śālivāhana śaka (aka. Shaka era): This epoch uses 78 CE as the starting year (Year 1). Hence, the Gregorian year 2025 CE would be 1947 Shaka era (starting with the cāndra māna yugādi that occurs in that Gregorian year). The historical antecedents of this era are uncertain.

Vikram Samvat: This epoch uses 57 BC as the starting year (Year 1). Hence, the Gregorian year 2025 CE would be 2082 Vikram Samvat (starting with the cāndra māna yugādi that occurs in that Gregorian year). The historical antecedents of this era too are uncertain and are linked to the legendary king Vikramaditya.

Note that neither of these eras is defined astronomically. The Hindu calendar does have astronomical eras (yuga, manvantara, kalpa), but they are intended for modelling exceptionally large, geological timeframes and are of little relevance to calendrics.

NAMING OF CĀNDRA VARṢA

A ***saṃvatsara*** is a year defined using the orbital movement of Jupiter, having a duration of 361 days, seven days short of the duration of a cāndra varṣa. saṃvatsara are named using sixty unique names—prabhava, vibhava, śukla, etc. Since saṃvatsara is a part of gurormāna, it is outside the scope of this handbook. There is a current practice of naming cāndra varṣa using the sixty names of saṃvatsara. This practice is astronomically misleading.

WHY TWELVE CĀNDRAMĀSA?

We have seen that in cāndra māna, a year is made up of twelve months. We can observe this same relationship in the Gregorian calendar, as well as in the Islamic calendar. Was it a coincidence that all these calendars chose twelve months to a year?

There is a fundamental astronomical reason behind the choice of twelve months to make a year. This has to do with an elementary astronomical ratio.

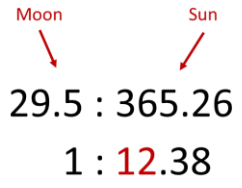
We know from modern astronomy that the Earth orbits the Sun in 365.26 days (in the geocentric model, it appears the other way—that the Sun orbits the Earth in 365.26 days). This fact is used to define a year in all solar calendars, such as the Gregorian calendar, as well as the saura māna Hindu calendar.

We have seen above that the Moon orbits the Earth, with respect to the Sun, in 29.5 days, and that is a lunar month.

The ratio of the orbital periods of the Moon and the Sun is 1 : 12.38. This means that twelve orbits of the Moon fit inside one orbit of the Sun, i.e., *the Moon is twelve times faster than the Sun.* By the time the Sun completes one orbit, the Moon would have completed 12.38 orbits.

Assigning 12 lunar months to a lunar year brings its duration close to a solar year, without exceeding it. In other words, months are defined by the Moon even if the year is defined by the Sun.

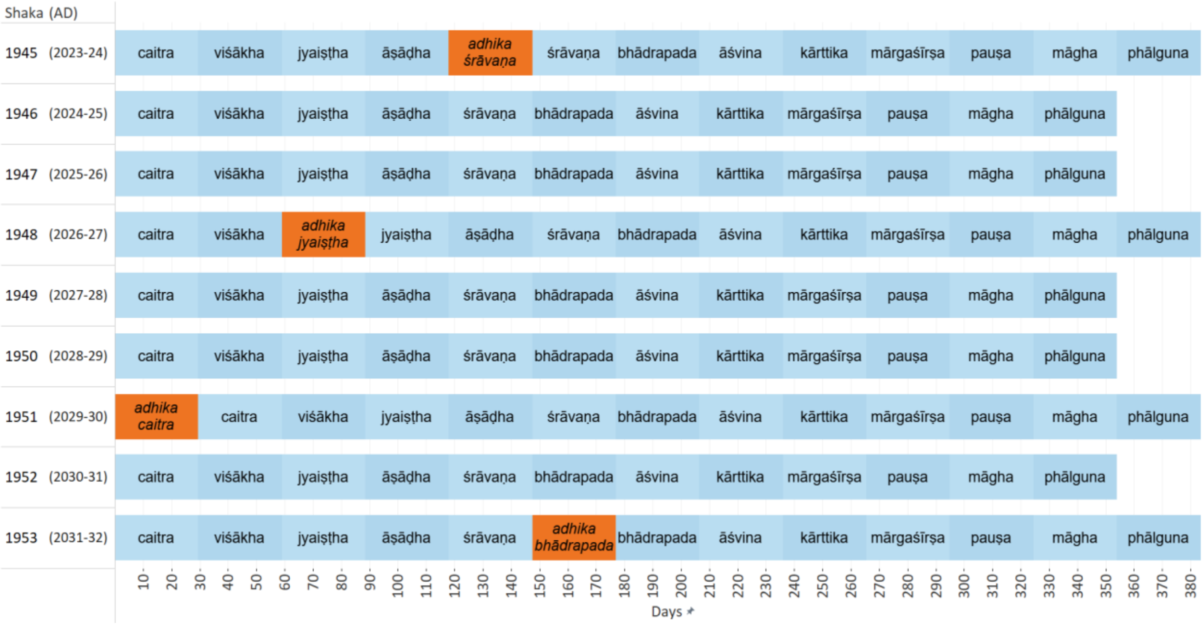
Ratio of the orbital periods of the Sun and the Moon



ADHIKA MĀSA

We know that a solar year is 365 days, and a lunar year is 354 days. Hence, the lunar year is 11 days short of the solar year. Assuming the solar and lunar years start on the same day, by the end of one year, they will fall apart by 11 days; the lunar New Year will occur 11 days before the solar New Year. Furthermore, this gap will widen year after year, becoming 22 days by the end of the second year, 33 days by the end of the third year, and so on. Thus, the solar and lunar years become increasingly unsynchronised, and the correspondence with the Gregorian months shown earlier becomes invalid over time.

In order to force a synchronisation between the lunar and solar years, a thirteenth month—***adhika māsa***, i.e., additional month—is introduced every third year. The additional thirteenth month may be introduced anytime during the year; it is named by prefixing the term *adhika* to the cāndramāsa name, e.g., adhika śrāvaṇa māsa; and it precedes the "real" month, i.e., *nija māsa,* of the same name. All these ideas are illustrated in the following figure:



This synchronisation is not perfect; the gap between the two New Years does not reduce to zero. And it is coarse-grained; an entire cāndramāsa is introduced instead of a precisely calculated number of days. As a result, occasionally an adhika māsa may be introduced in the second year instead of every third year (e.g., 2031-32 AD, as shown above).

Synchronisation of lunar and solar years is a complex topic. It requires a thorough understanding of saura māna too; hence, further details are beyond the scope of this handbook.

TITHI

Each pakṣa is divided into 15 *tithi*.

We know that in each pakṣa, the elongation of the Moon changes by 180°.

Hence, a ***tithi*** is the time taken by the Moon to change its elongation by 12° (180° ÷ 15), starting from immediately after an amāvāsyā (**Plate 13**) or pūrṇimā (**Plate 14**).

Names of tithi

1st tithi	prathama tithi	
2nd tithi	dvitīya tithi	
3rd tithi	tṛtīya tithi	
4th tithi	caturthī tithi	
5th tithi	pañcamī tithi	
6th tithi	ṣaṣṭhī tithi	
7th tithi	saptamī tithi	
8th tithi	aṣṭamī tithi	
9th tithi	navamī tithi	
10th tithi	daśamī tithi	
11th tithi	ekādaśī tithi	(eka-daśa, i.e., one-ten)
12th tithi	dvādaśī tithi	(dvau-daśa, i.e., two-ten)
13th tithi	trayodaśī tithi	(traya-daśa, i.e., three-ten)
14th tithi	caturdaśī tithi	(catur-daśa, i.e., four-ten)
15th tithi	pūrṇimā tithi / amāvāsyā tithi	

Tithi are identified by their position in the sequence, using the Sanskrit words for 1st, 2nd, 3rd, etc.

The 15th tithi should be pañcadaśī tithi, i.e., five-ten. Instead, the terms pūrṇimā and amāvāsyā are reused, postfixed by the word *tithi*.

The 15th tithi of śukla pakṣa is referred to as ***pūrṇimā tithi*** since this period leads up to the moment of pūrṇimā, i.e., pūrṇimā tithi ends with pūrṇimā (**Plate 15**).

The 15th tithi of kṛṣṇa pakṣa is referred to as ***amāvāsyā tithi*** since this period leads up to the moment of amāvāsyā, i.e., amāvāsyā tithi ends with amāvāsyā (**Plate 16**).

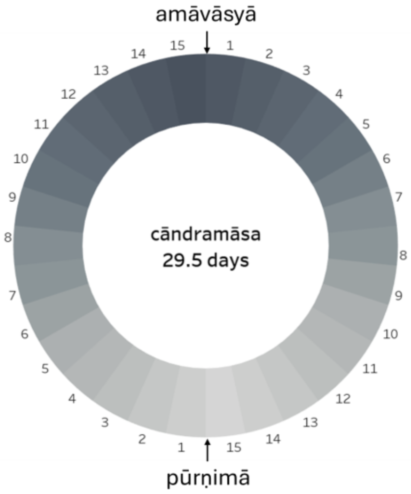
For better understanding, the range of elongation of the Moon that constitutes each tithi is listed in the following tables. It is easy to see that these are nothing but the very familiar twelve times tables.

	#	tithi	elongation of the Moon
śukla pakṣa	1	prathama tithi	> E0°to E12°
	2	dvitīya tithi	> E12° to E24°
	3	tṛtīya tithi	> E24° to E36°
	4	caturthī tithi	> E36° to E48°
	5	pañcamī tithi	> E48° to E60°
	6	ṣaṣṭhī tithi	> E60° to E72°
	7	saptamī tithi	> E72° to E84°
	8	aṣṭamī tithi	> E84° to E96°
	9	navamī tithi	> E96° to E108°
	10	daśamī tithi	> E108° to E120°
	11	ekādaśī tithi	> E120° to E132°
	12	dvādaśī tithi	> E132° to E144°
	13	trayodaśī tithi	> E144° to E156°
	14	caturdaśī tithi	> E156° to E168°
	15	pūrṇimā tithi	> E168° to E180°

	#	tithi	elongation of the Moon
kṛṣṇa pakṣa	1	prathama tithi	< W180° to W168°
	2	dvitīya tithi	< W168° to W156°
	3	tṛtīya tithi	< W156° to W144°
	4	caturthī tithi	< W144° to W132°
	5	pañcamī tithi	< W132° to W120°
	6	ṣaṣṭhī tithi	< W120° to W108°
	7	saptamī tithi	< W108° to W96°
	8	aṣṭamī tithi	< W96° to W84°
	9	navamī tithi	< W84° to W72°
	10	daśamī tithi	< W72° to W60°
	11	ekādaśī tithi	< W60° to W48°
	12	dvādaśī tithi	< W48° to W36°
	13	trayodaśī tithi	< W36° to W24°
	14	caturdaśī tithi	< W24° to W12°
	15	amāvāsyā tithi	< W12° to W0°

DURATION OF TITHI

The durations of tithi vary. This variation comes about because the orbits of the Sun and the Moon are slightly elliptical, and their angular velocities are not constant.



The duration of a tithi is approximately one day (24 hours), give or take a few hours. The reason is as follows:

The duration of a pakṣa is 14.75 days. By dividing this into 15 tithi, each tithi is made to approximate one day (14.75 days ÷ 15 ≈ 1 day).

Since the duration of a tithi is approximately one day, a tithi is often informally referred to as a *lunar day.*

The fact that the duration of a tithi can be greater than or less than 24 hours leads to some interesting situations that are explained below.

TITHI AND SOLAR DAY

As seen from the above definition, a tithi has absolutely no correlation with a solar day; it has nothing to do with the rising and setting of the Sun. A tithi can end, and the next tithi begin, at any time of the day or night (**Plate 17**).

Yet, all human life is governed by the solar day; we rise with the Sun and begin our daily activities. As a result, in the Hindu calendar, a day is defined as the period from one sunrise to the next.

Hence, the following question arises: “In the Hindu calendar, what is the tithi associated with a given day?” Since a tithi can end any time of the day (or night), most solar days straddle two tithi (**Plate 18**), making it difficult to answer this question. Hence, the following convention is applied:

The tithi prevailing at sunrise is used to identify the entire day, irrespective of how long that tithi lasts. In the example shown in Plate 18, ṣaṣṭhī tithi ends at 12:21 PM, i.e., ṣaṣṭhī tithi lasts only six and a half hours after sunrise, and the remaining seventeen and a half hours of the day are saptamī tithi. Yet, the entire 21 Dec 2024 is identified as ṣaṣṭhī tithi.

This convention is set aside when it comes to deciding the time for performing religious ceremonies (pūja muhūrta). In that situation, Hindu priests consider the change in tithi and prescribe the appropriate date and time.

ADHIKA TITHI

Sometimes it happens that a tithi extends across two days, i.e., the same tithi prevails across two sunrises (**Plate 19**). In this case, it appears as if two successive days have the same tithi, i.e., the tithi repeats in the Hindu calendar (**Plate 20**). The repeated tithi is known as an ***adhika tithi***, i.e., additional tithi; in the example shown in Plate 20, 19th Jan 2025 is referred to as an adhika pañcamī.

KṢAYA TITHI

Sometimes it happens that a tithi is embedded entirely inside one day, i.e., the entire tithi starts and ends between two sunrises (**Plate 21**). Such a tithi is known as a ***kṣaya tithi***, i.e., lost tithi. In this case, it appears as if the calendar entirely skips this tithi (**Plate 22**).

A DAY IN THE HINDU CALENDAR

In the Hindu cāndra māna calendar, a day is uniquely represented by a combination of cāndramāsa, pakṣa and tithi. As mentioned above, the tithi prevailing at sunrise is used to identify the entire day.

Moden calendar	30th March 2025
Hindu calendar	caitra māsa, śukla pakṣa, prathama tithi of 1947 (Shaka era) / 2082 (Viram Samvat)

HINDU FESTIVALS

The dates of most Hindu festivals are fixed using the cāndra māna calendar. The dates of some of the major Hindu festivals are shown below:

festival	**cāndramāsa**		**pakṣa**	**tithi**
	amānta	**pūrṇimānta**		
Chandramana Yugadi	caitra		śukla	prathama
Rama Navami	caitra		śukla	navamī
Akshaya Tritiya	vaiśākha		śukla	tṛtīya
Naga Panchami	śrāvaṇa		śukla	pañcamī
Raksha Bandan	śrāvaṇa		śukla	pūrṇimā
Krishna Janmashtami	śrāvaṇa	bhādrapada	kṛṣṇa	aṣṭamī
Ganesha Chaturthi	bhādrapada		śukla	caturthī
Mahalaya Amavasya	bhādrapada	āśvina	kṛṣṇa	amāvāsyā
Dussehra				
Durgashtami	āśvina		śukla	aṣṭamī
Maha Navami	āśvina		śukla	navamī
Vijaya Dashami	āśvina		śukla	daśamī
Karva Chauth	āśvina	kārttika	kṛṣṇa	caturthī
Deepavali				
Dhan Teras	āśvina	kārttika	kṛṣṇa	trayodaśī
Naraka Chaturdashi	āśvina	kārttika	kṛṣṇa	caturdaśī
Lakshmi Puja	āśvina	kārttika	kṛṣṇa	amāvāsyā
Bali Padyami	kārttika		śukla	prathama
Bhai Dooj	kārttika		śukla	dvitīya
Skanda Shashti	kārttika		śukla	ṣaṣṭhī

festival	cāndramāsa		pakṣa	tithi
	amānta	pūrṇimānta		
Shiva Ratri	māgha	phālguna	kṛṣṇa	caturdaśī
Holi	phālguna		śukla	pūrṇimā

The dates of these festivals do not change from one year to the next on the Hindu calendar, but when we look up these festivals on the Gregorian calendar, their dates do change. This happens because the duration of a cāndra varṣa and a year in the Gregorian calendar differ by 11 days (365 days minus 354 days). As a result, every year, Hindu festivals occur ~11 days earlier on the Gregorian calendar with respect to the previous year; except in a cāndra varṣa which includes an adhika māsa, in which case they occur ~19 days later (29.5 days minus 11 days). **Plate 23** illustrates these ideas.

Since most tithi span two days, the question arises as to which of the two days should be chosen to celebrate each festival. Not all pañcāṅga agree on the exact date; some pañcāṅga may choose one day while some others the next day, i.e., a one-day variation is possible.

Furthermore, some festivals have multiple definitions, e.g., Krishna Janmashtami has a lunar definition (shown above) and a luni-solar definition (siṁha māsa, rohiṇī nakṣatra, aṣṭamī tithi), thus causing a variation in festival dates across communities.

CONCLUSION

The Hindu calendar has a sound astronomical basis. In this handbook, we have explained the astronomy of the lunar portion of the Hindu calendar—cāndra māna.

At one level, the Hindu calendar models a ginormous celestial clock, high up in the sky, with a Sun hand and a Moon hand (**Plate 24**). While the Moon hand tracks the pakṣa and tithi, the Sun hand tracks the cāndramāsa. Our ancestors read this celestial clock with a high degree of precision and codified its operation into the Hindu pañcāṅga.

At another level, the Hindu calendar represents a delightful celestial dance—the dance of the Sun and the Moon. As the Moon moves apart from the Sun and comes back to it, the fortnights and months are defined. Twelve such partings and meetings of the Moon and the Sun define the year, and every 12-degree step the Moon takes defines the lunar day.

The idea of a celestial, cosmic dance is deeply embedded in Hindu culture by the imagery of Nataraja (**Plate 25**). Divinity permeates everything, from the smallest atom to the largest galaxy. Divinity animates everything, from the whisper of a breeze to the thunder of a cyclone. The dance of divinity is the movement of the entire universe. A minuscule portion of that dance—the movement of the Sun and the Moon—has been encoded into the Hindu pañcāṅga. The pañcāṅga has survived over millennia, but the astronomy has been lost. The time has come to recover that astronomy and to understand the science behind the Hindu pañcāṅga.

With understanding comes appreciation.

APPENDIX A– HOW THE CĀNDRAMĀSA GOT THEIR NAMES

NAKṢATRA

When faced with the immensity of the sky, studded with countless stars, ancient astronomers resorted to segmentation. In one well-known arrangement—known as the zodiac/rāśi maṇḍala—the ecliptic was divided into twelve equal segments. Long before the signs of the zodiac were invented, Hindu seers divided the ecliptic into twenty-seven equal segments, known as the nakṣatra maṇḍala.

The term nakṣatra has multiple meanings in Sanskrit.

1. ***nakṣatra*** means a star, e.g., rohiṇī, ārdrā, maghā, citrā, svātī.
2. ***nakṣatra*** also means an asterism, i.e., a collection of stars, e.g., aśvinī, bharaṇī, kṛttikā. It is customary to connect the stars in an asterism with imaginary lines in order to visualise imaginary figures in the sky. One star within each asterism is designated as its ***yogatārā,*** i.e., principal star, for astronomical purposes.
3. Of these nakṣatra, those that are in the vicinity of the ecliptic were of special interest for ancient Hindu astronomers. They divided the ecliptic into twenty-seven equal segments of $13.\overline{3}$ degrees each (360° ÷ 27 = 13° 20‘) and used the names of nearby nakṣatra to identify these segments. Each segment is referred to as a ***nakṣatra***. Collectively, these segments form the ***nakṣatra maṇḍala***.
4. To connect these nakṣatra to time and the calendar, we turn to the Moon. The time taken by the Moon to traverse a nakṣatra segment determines the ***duration of that nakṣatra***.

   The number twenty-seven was chosen in order to synchronise these segments with the sidereal orbital period of the Moon—27.3 days. The Moon traverses the entire nakṣatra maṇḍala in 27.3 days. It follows that the Moon traverses one nakṣatra in approximately one day (27.3 days ÷ 27). The colourful legend of the Moon and his twenty-seven wives is a metaphor for this celestial movement.

   It is easy to see from these definitions that nakṣatra is similar to tithi and hence can also be considered informally as a lunar day. The concepts of adhika and kṣaya nakṣatra too are defined analogously to adhika and kṣaya tithi, respectively.

5. The nakṣatra segment in which the Moon is at the time of a baby's birth, is said to be the ***janma nakṣatra*** (i.e., the birth star) of that baby.

Plate 26 illustrates the points above; if a baby was born in Bengaluru on 15 April 2022 at 8:09 PM IST, the janma nakṣatra of that baby would be hasta.

The following table lists the names of the nakṣatra:

1. aśvinī
2. bharaṇī
3. kṛttikā
4. rohiṇī
5. mṛgaśiras
6. ārdrā
7. punarvasu
8. puṣyā
9. aśleṣā
10. maghā
11. pūrva phālgunī
12. uttara phālgunī
13. hasta
14. citrā
15. svātī
16. viśākhā
17. anurādhā
18. jyeṣṭhā
19. mūla
20. pūrva āṣāḍhā
21. uttara āṣāḍhā
22. śravaṇa
23. dhaniṣṭhā
24. śatabhiṣa
25. pūrva bhādrapada
26. uttara bhādrapada
27. revatī

Note that in the above list, three names repeat twice with the prefixes pūrva and uttara, viz., phālgunī, āṣāḍha and bhādrapada (**Plate 27**). This leads us to believe these were originally identified as three asterisms, but they were each too big to fit inside 13° 20' segments. Hence, they were split in pairs to force-fit them into 13° 20' segments. Their original names were retained with the prefixes *pūrva,* i.e., former and *uttara,* i.e., latter. These prefixes indicate the order in which the Moon (and the Sun) traverse these nakṣatra, e.g., the Moon traverses pūrva phālgunī first and then moves into uttara phālgunī.

NAKṢATRA AND CĀNDRAMĀSA

When naming cāndramāsa, ancient Hindu astronomers reused the names of some of these nakṣatra with slight modifications, rather than invent new names.

cāndramāsa	**nakṣatra**
caitra māsa	citrā nakṣatra
vaiśākha māsa	viśākhā nakṣatra
jyaiṣṭha māsa	jyeṣṭhā nakṣatra
āṣāḍha māsa	āṣāḍhā nakṣatra
śrāvaṇa māsa	śravaṇa nakṣatra
bhādrapada māsa	bhādrapada nakṣatra
āśvina māsa	aśvinī nakṣatra
kārttika māsa	kṛttikā nakṣatra
mārgaśīrṣa māsa	mṛgaśiras nakṣatra
pauṣa māsa	puṣyā nakṣatra
māgha māsa	maghā nakṣatra
phālguna māsa	phālgunī nakṣatra

The question arises as to why these specific nakṣatra were chosen to name the cāndramāsa. The answer lies in the observation that the full moon (pūrṇimā) of each cāndramāsa occurs in the vicinity of that nakṣatra. For example, caitra pūrṇimā occurs in the vicinity of citrā nakṣatra, vaiśākha pūrṇimā occurs in the vicinity of viśākhā nakṣatra, and so on.

This rule is not precise (hence, the phrase "in the vicinity of"). cāndramāsa are based on the synodic orbital period of the Moon (29.5 days). nakṣatra maṇḍala is based on the sidereal orbital period of the Moon (27.3 days). This leads to the occurrences of full moon drifting across the nakṣatra maṇḍala by ~30° every month. The introduction of adhika māsa has the secondary effect of arresting this drift, thus ensuring that full moon occurs somewhere in the vicinity of the nakṣatra which lends its name to the cāndramāsa (**Plate 28**). A complete list of possibilities is shown below:

cāndramāsa	**nakṣatra in which pūrṇimā may occur**
caitra māsa	citrā / svātī
vaiśākha māsa	viśākhā / anurādhā
jyaiṣṭha māsa	jyeṣṭhā / mūla
āṣāḍha māsa	pūrva āṣāḍhā / uttara āṣāḍhā
śrāvaṇa māsa	śravaṇa / dhaniṣṭhā
bhādrapada māsa	śatabhiṣa / pūrva bhādrapada / uttara bhādrapada
āśvina māsa	revatī / aśvinī / bharaṇī
kārttika māsa	kṛttikā / rohiṇī
mārgaśīrṣa māsa	mṛgaśiras / ārdrā
pauṣa māsa	punarvasu / puṣyā
māgha māsa	aśleṣā / maghā
phālguna māsa	pūrva phālgunī / uttara phālgunī / hasta

APPENDIX B - ILLUSTRATIONS

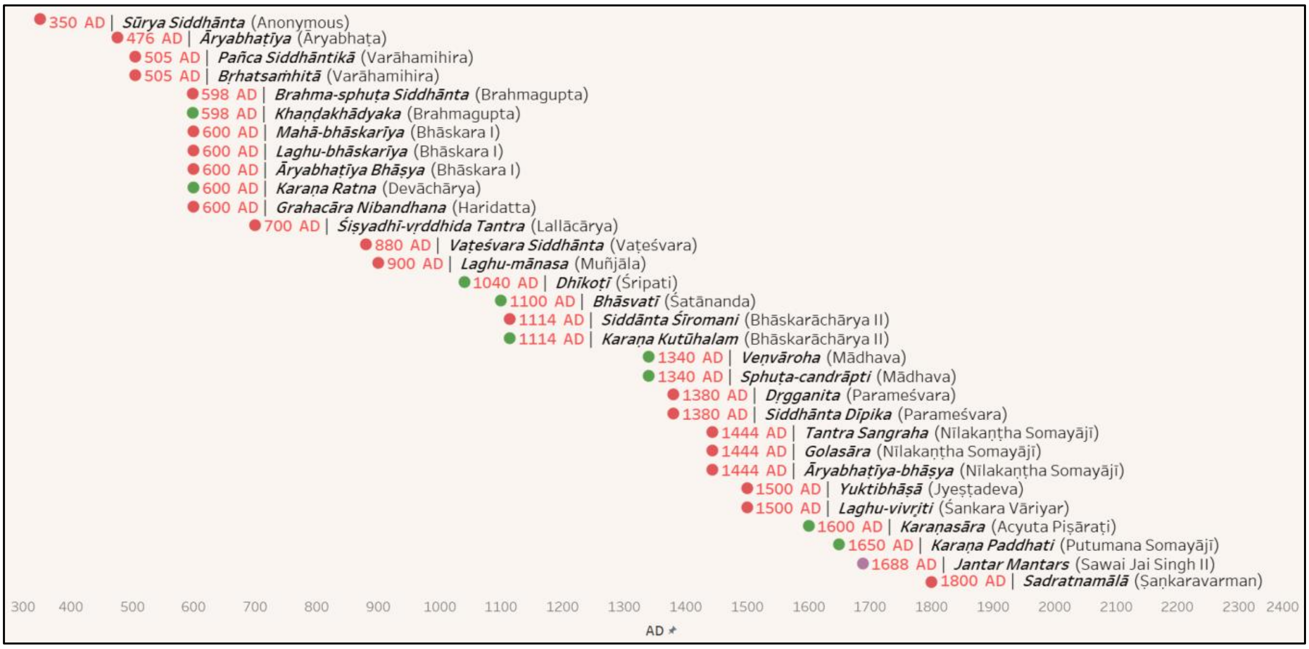


Plate 1 – 1500 years of Hindu astronomy

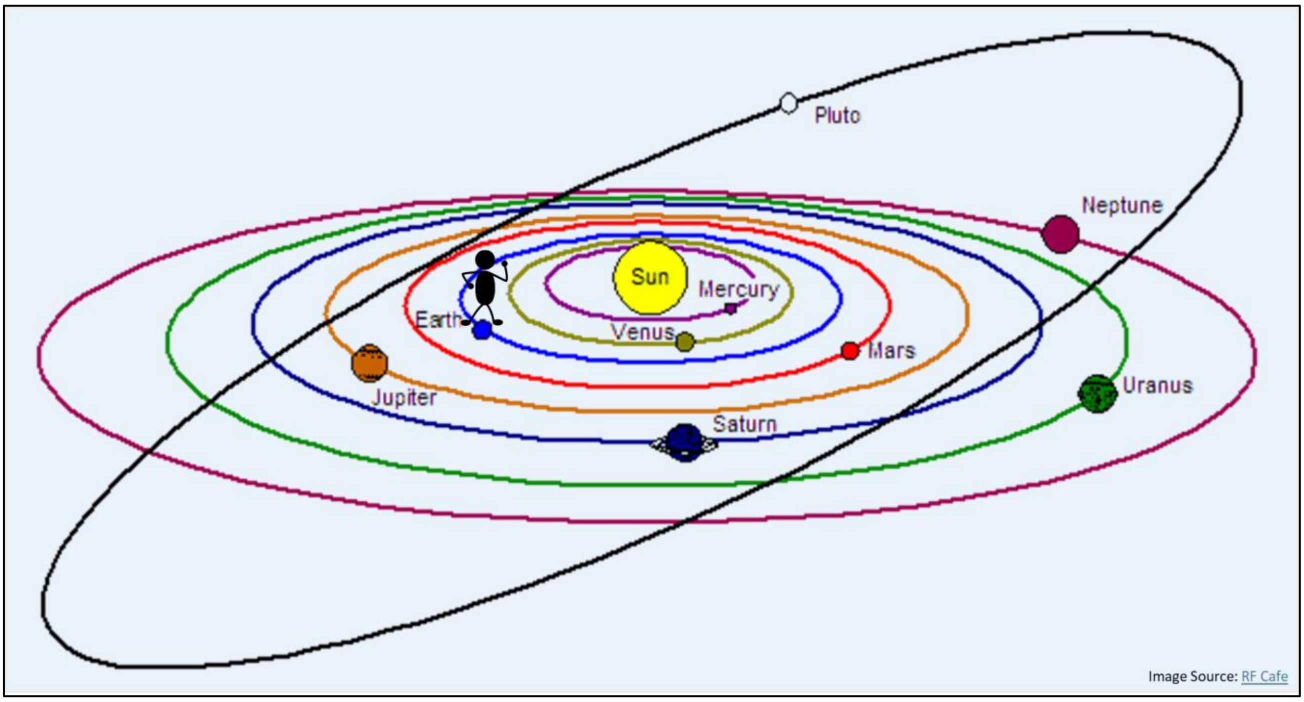


Image Source: RF Cafe

Plate 2 – the solar system as seen from outer space

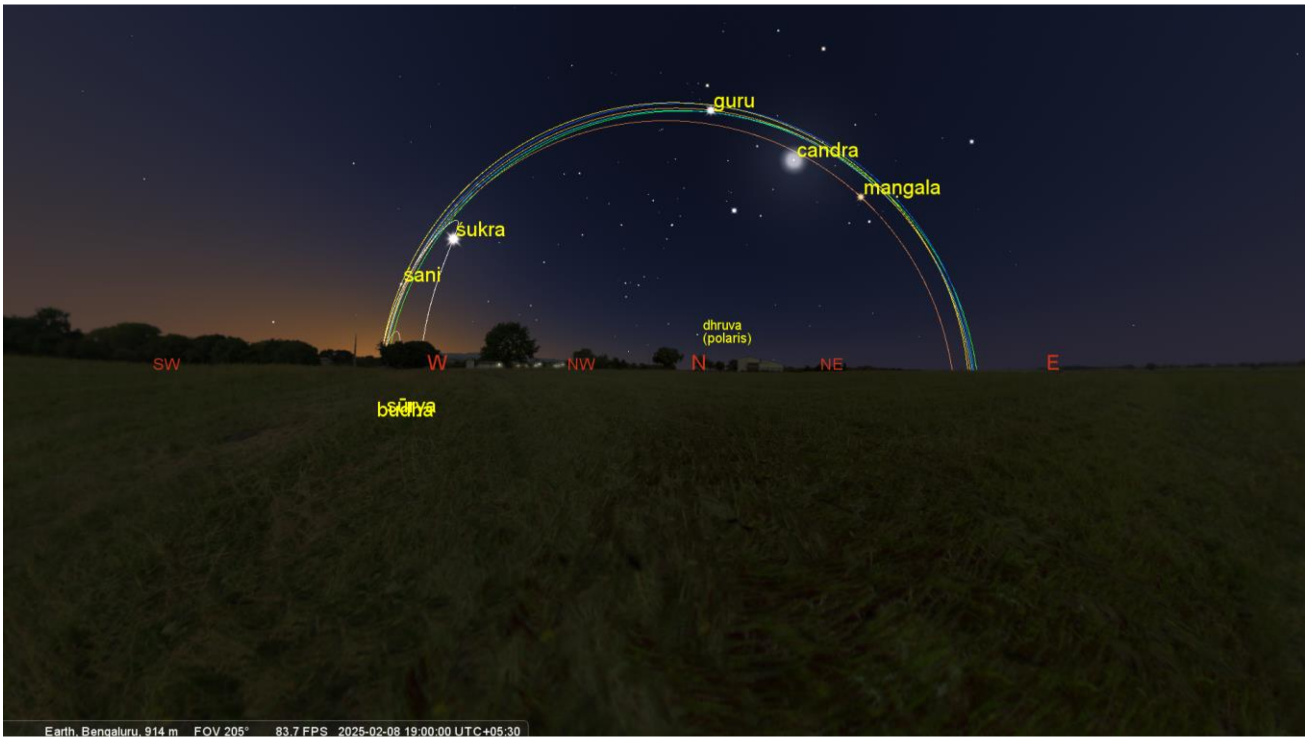


Plate 3 – the solar system as seen by an observer standing on the surface of the Earth

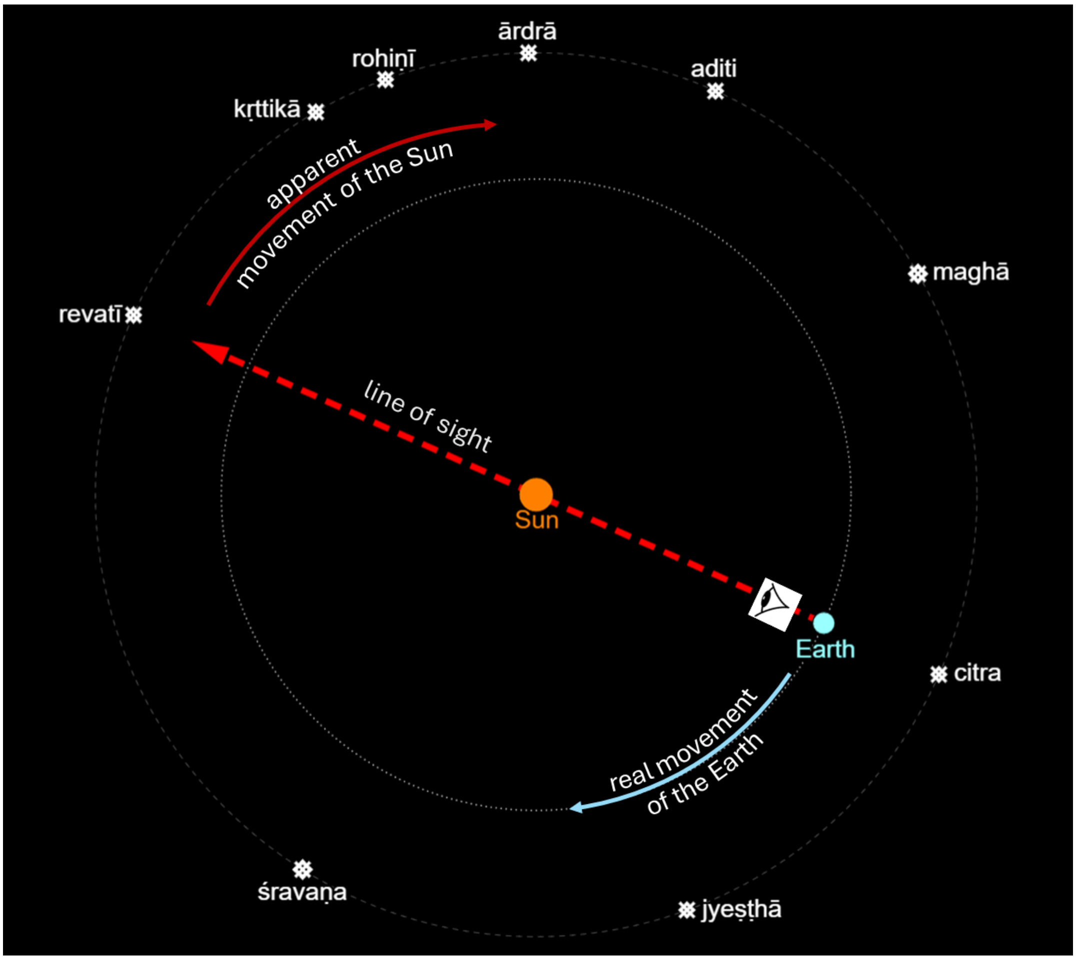


Plate 4 – apparent movement of the Sun across the stars

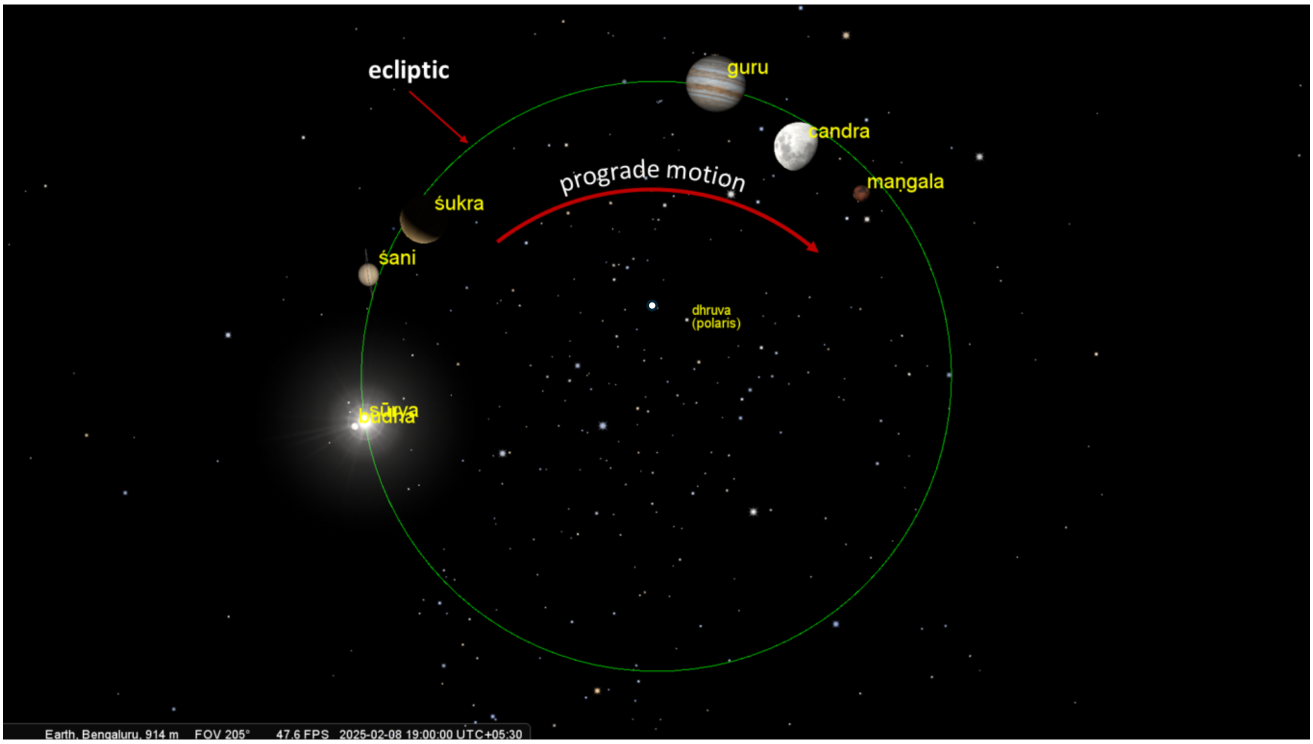


Plate 5 – Ahargana model

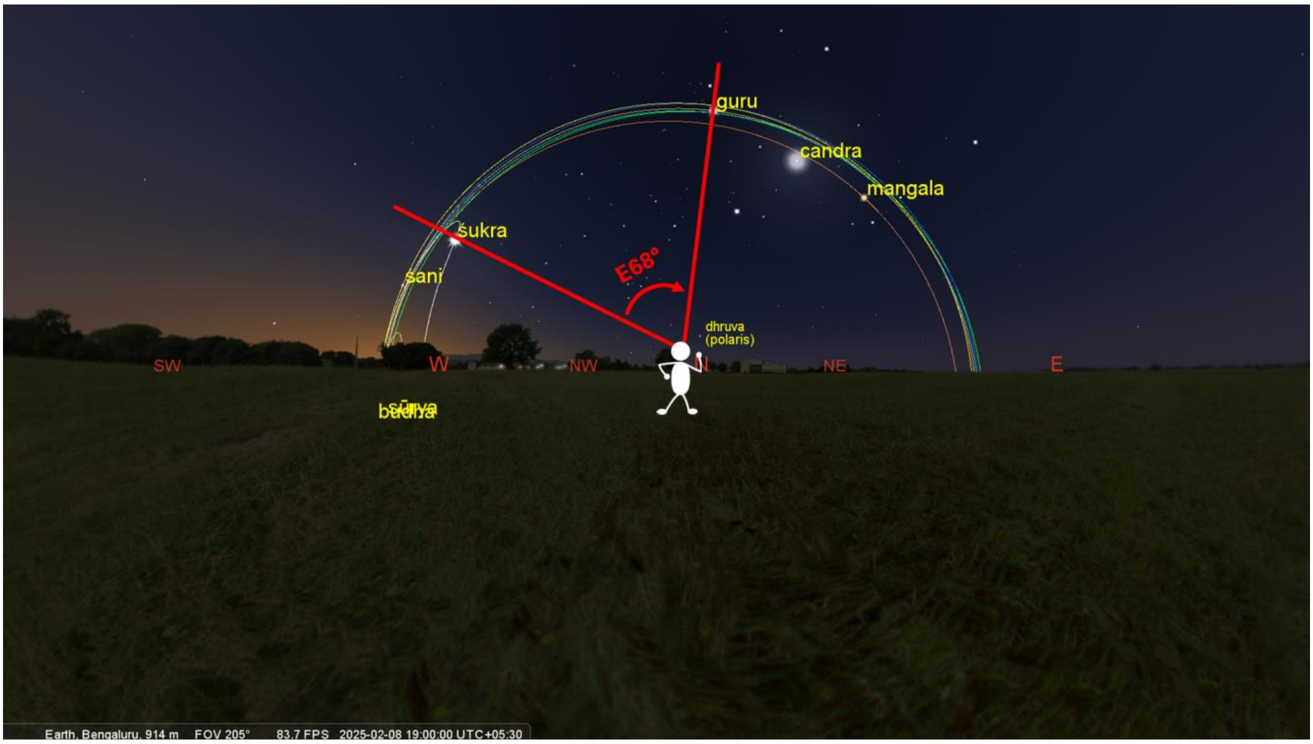
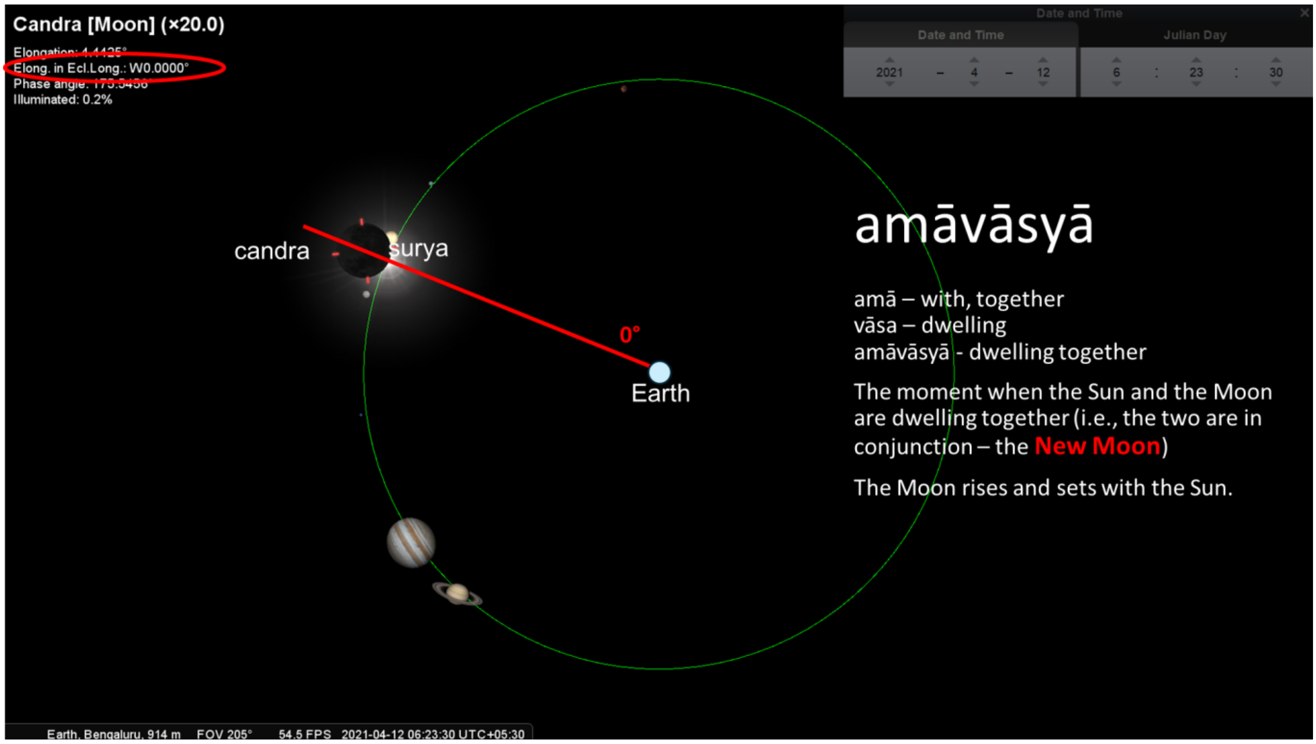


Plate 6 – angular distance between celestial bodies



Candra [Moon] (×20.0)

Elongation: 4.4425°
Elong. in Ecl.Long.: W0.0000°
Phase angle: 175.5456°
Illuminated: 0.2%

amāvāsyā

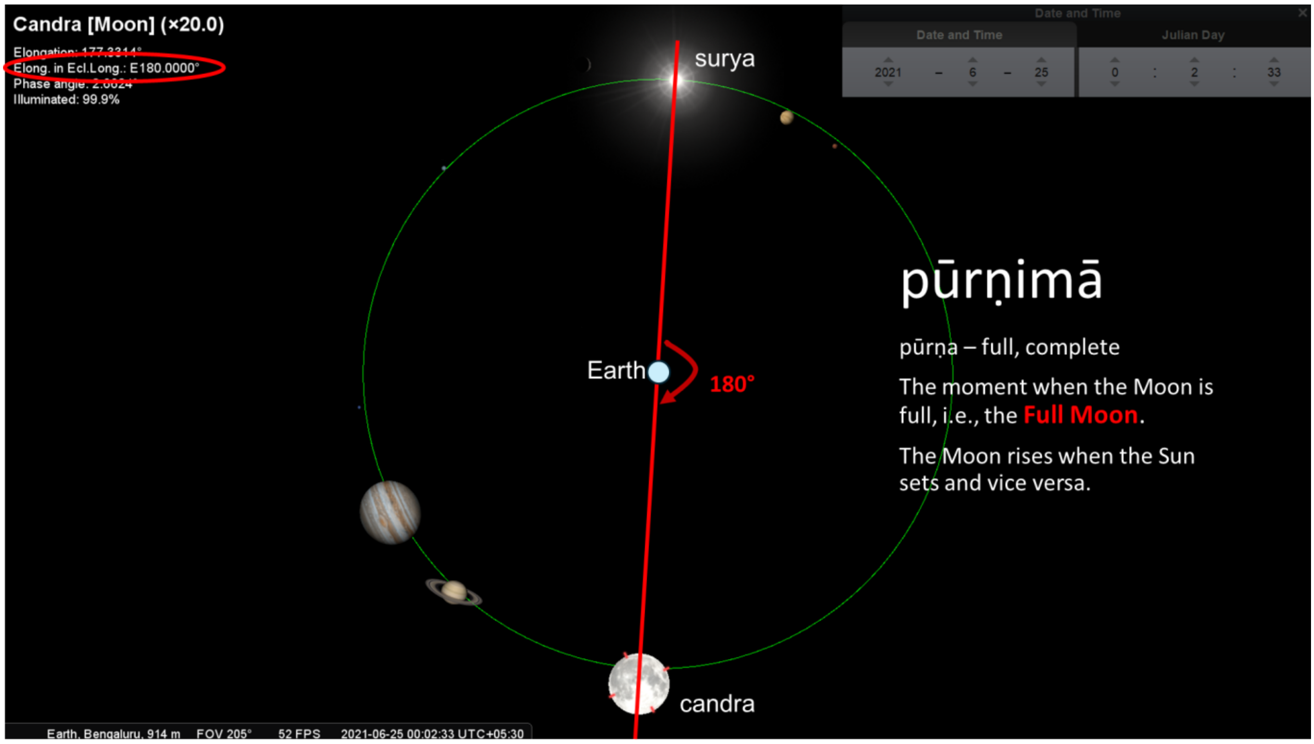
amā – with, together
vāsa – dwelling
amāvāsyā - dwelling together

The moment when the Sun and the Moon are dwelling together (i.e., the two are in conjunction – the **New Moon**)

The Moon rises and sets with the Sun.

Earth, Bengaluru, 914 m FOV 205° 54.5 FPS 2021-04-12 06:23:30 UTC+05:30

Plate 7 – amāvāsyā



Candra [Moon] (×20.0)

Elongation: 177.3314°
Elong. in Ecl.Long.: E180.0000°
Phase angle: 2.6624°
Illuminated: 99.9%

pūrṇimā

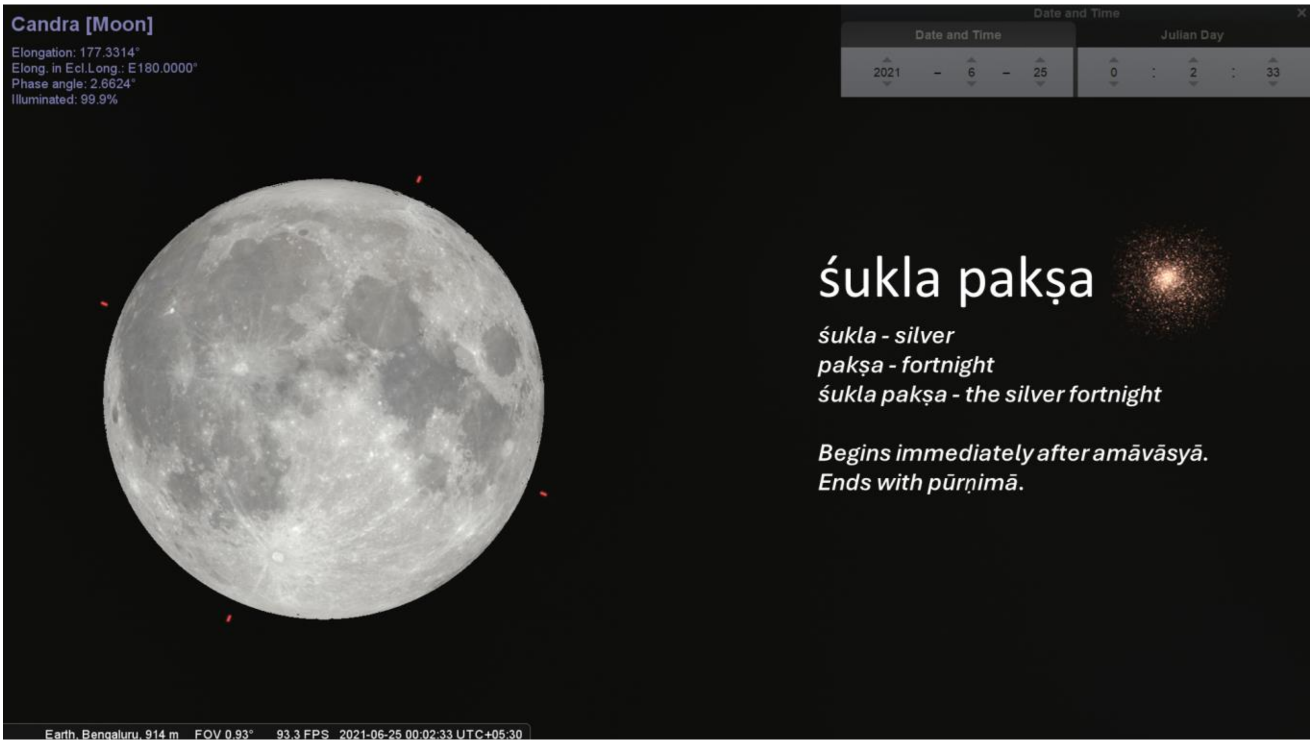
pūrṇa – full, complete

The moment when the Moon is full, i.e., the **Full Moon**.

The Moon rises when the Sun sets and vice versa.

Earth, Bengaluru, 914 m FOV 205° 52 FPS 2021-06-25 00:02:33 UTC+05:30

Plate 8 – pūrṇimā



Candra [Moon]

Elongation: 177.3314°
Elong. in Ecl.Long.: E180.0000°
Phase angle: 2.6624°
Illuminated: 99.9%

śukla pakṣa

śukla - silver
pakṣa - fortnight
śukla pakṣa - the silver fortnight

Begins immediately after amāvāsyā.
Ends with pūrṇimā.

Earth, Bengaluru, 914 m FOV 0.93° 93.3 FPS 2021-06-25 00:02:33 UTC+05:30

Plate 9 – pūrṇimā marks the end of śukla pakṣa

Candra [Moon]

Elongation: 4°26'32.9"
Elong. in Ecl.Long.: W0°00'00"
Phase angle: +175°32'44.0"
Illuminated: 0.2%

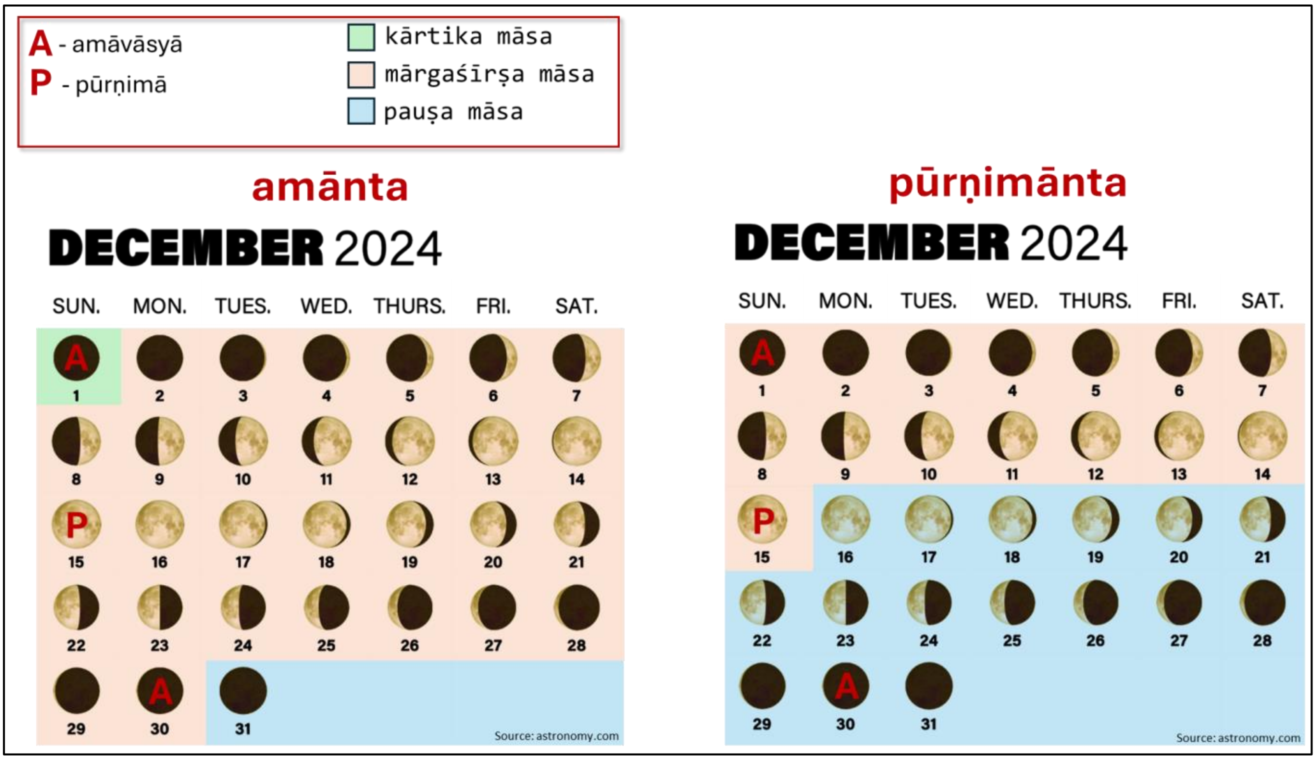
kṛṣṇa pakṣa

kṛṣṇa - black
pakṣa - fortnight
kṛṣṇa pakṣa - the black fortnight

Begins immediately after pūrṇimā.
Ends with amāvāsyā.

Earth, Bengaluru, 914 m FOV 0.813° 42.9 FPS 2021-04-12 06:23:30 UTC+05:30

Plate 10 – amāvāsyā marks the end of kṛṣṇa pakṣa



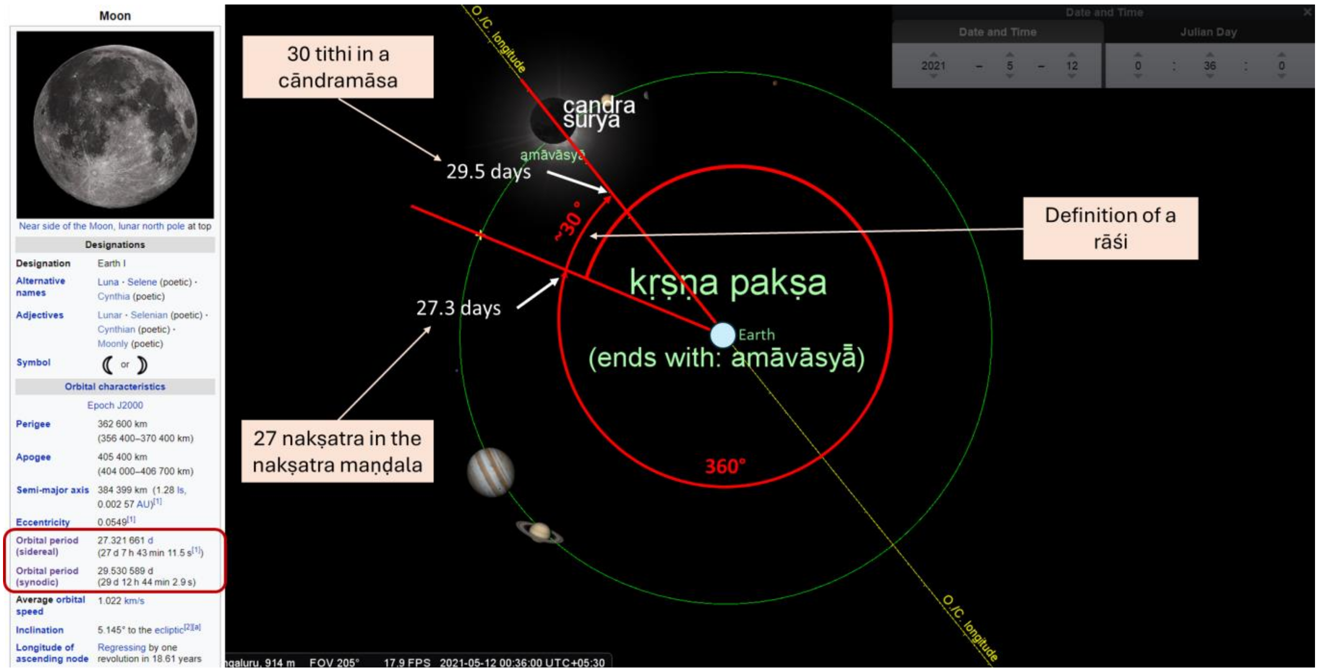
SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
A 1	2	3	4	5	6	7
8	9	10	11	12	13	14
P 15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	A 30	31				

Source: astronomy.com

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
A 1	2	3	4	5	6	7
8	9	10	11	12	13	14
P 15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	A 30	31				

Source: astronomy.com

Plate 11 – amānta vs. pūrṇimānta calendars


Moon

Near side of the Moon, lunar north pole at top

Designations	
Designation	Earth I
Alternative names	Luna · Selene (poetic) · Cynthia (poetic)
Adjectives	Lunar · Selenian (poetic) · Cynthian (poetic) · Moonly (poetic)
Symbol	☾ or ☽
Orbital characteristics	
Epoch J2000	
Perigee	362 600 km (356 400–370 400 km)
Apogee	405 400 km (404 000–406 700 km)
Semi-major axis	384 399 km (1.28 ls, 0.002 57 AU)[1]
Eccentricity	0.0549[1]
Orbital period (sidereal)	27.321 661 d (27 d 7 h 43 min 11.5 s[1])
Orbital period (synodic)	29.530 589 d (29 d 12 h 44 min 2.9 s)
Average orbital speed	1.022 km/s
Inclination	5.145° to the ecliptic[2][a]
Longitude of ascending node	Regressing by one revolution in 18.61 years

Plate 12 – the two orbital periods of the Moon

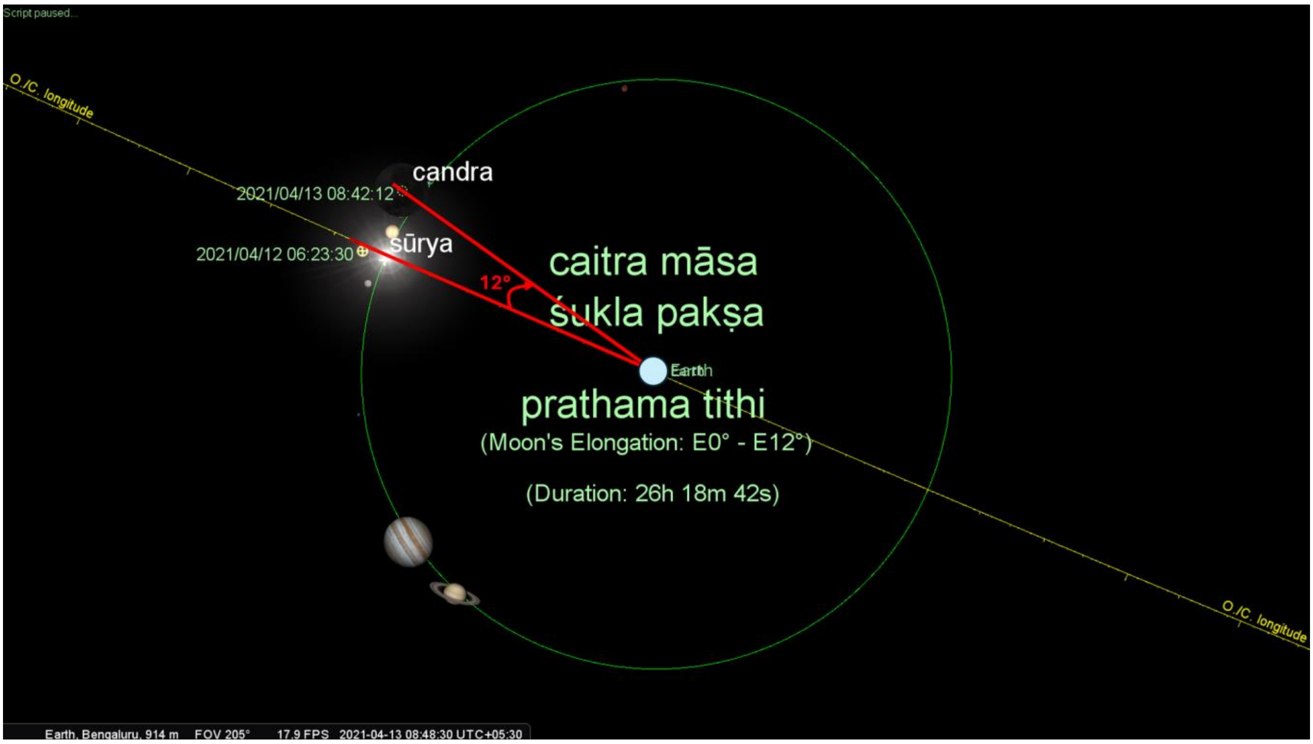


Plate 13 – prathama tithi of śukla pakṣa ends

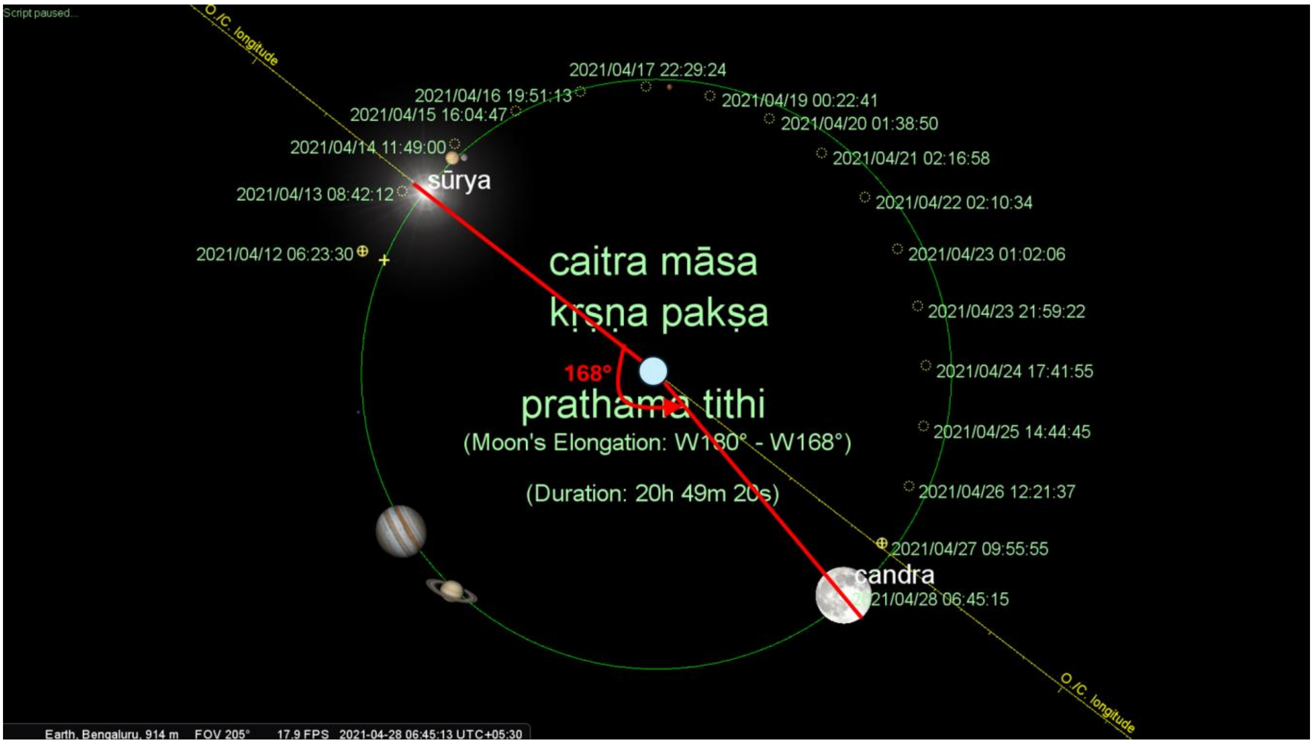


Plate 14 – prathama tithi of kṛṣṇa pakṣa ends

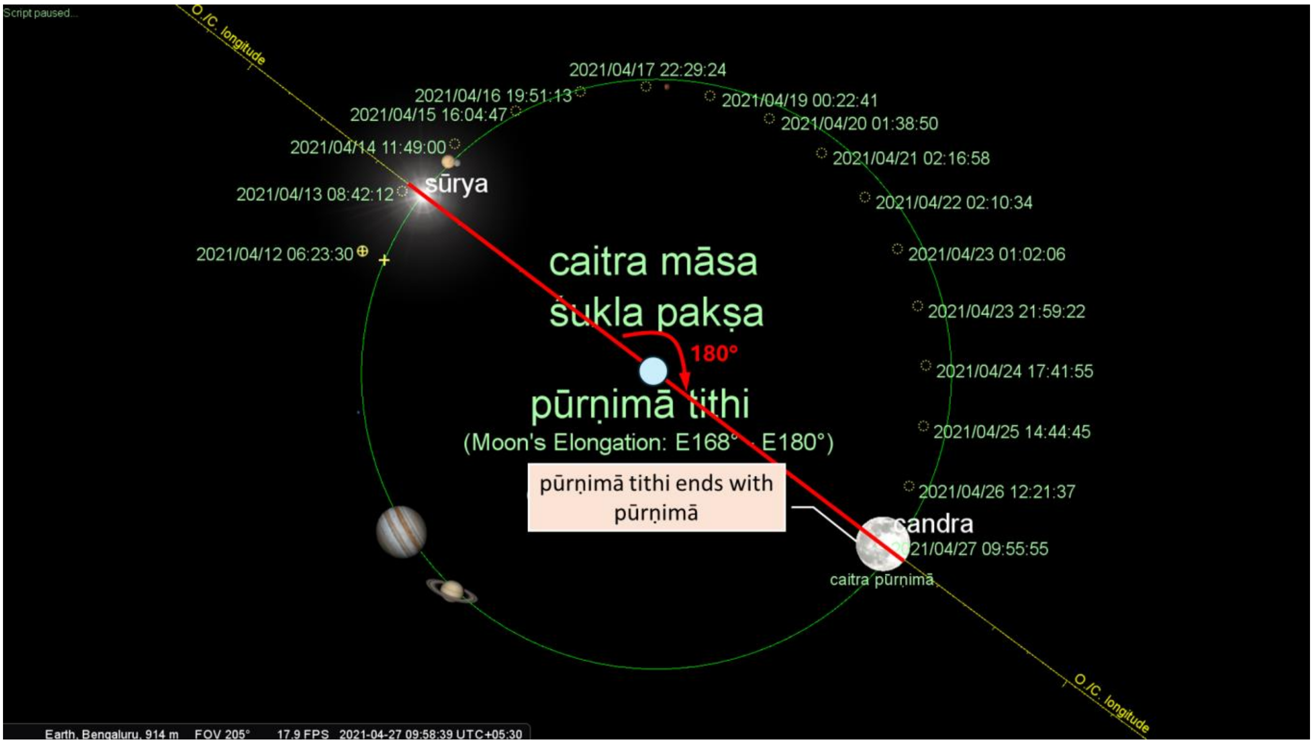


Plate 15 – pūrṇimā tithi ends with the moment of pūrṇimā

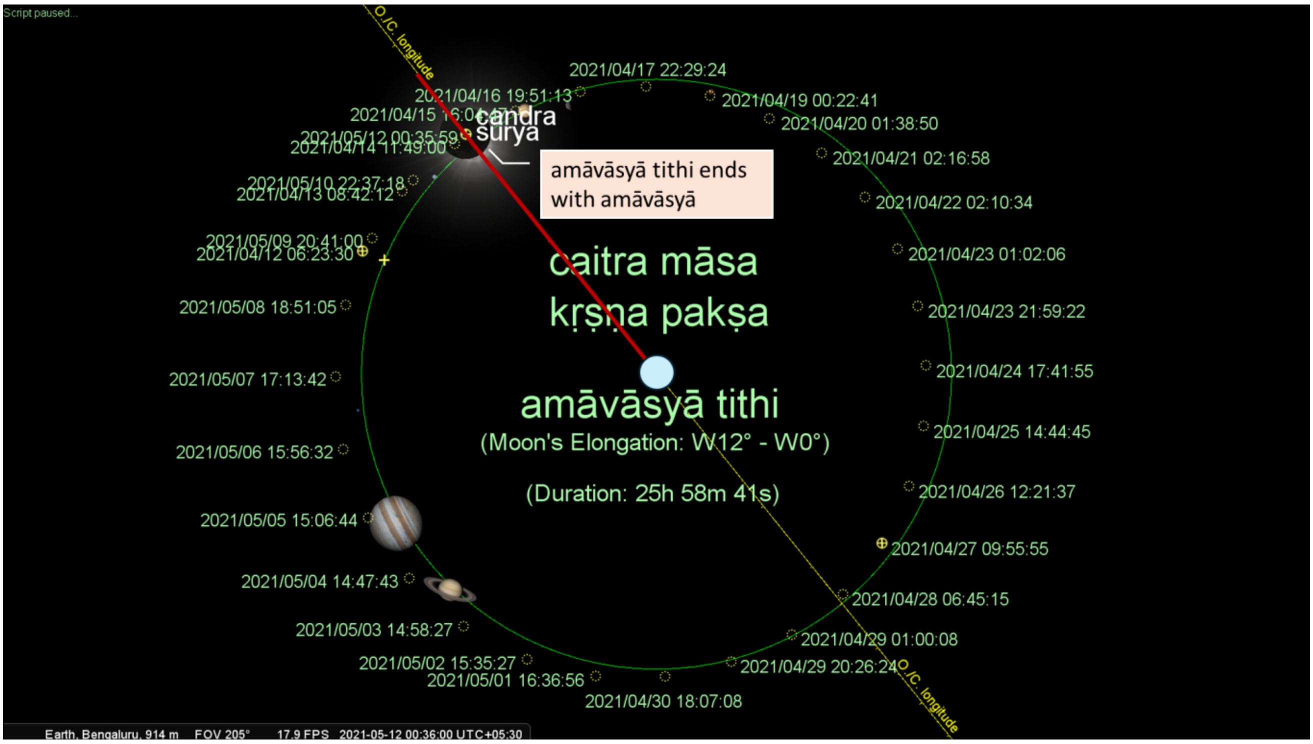
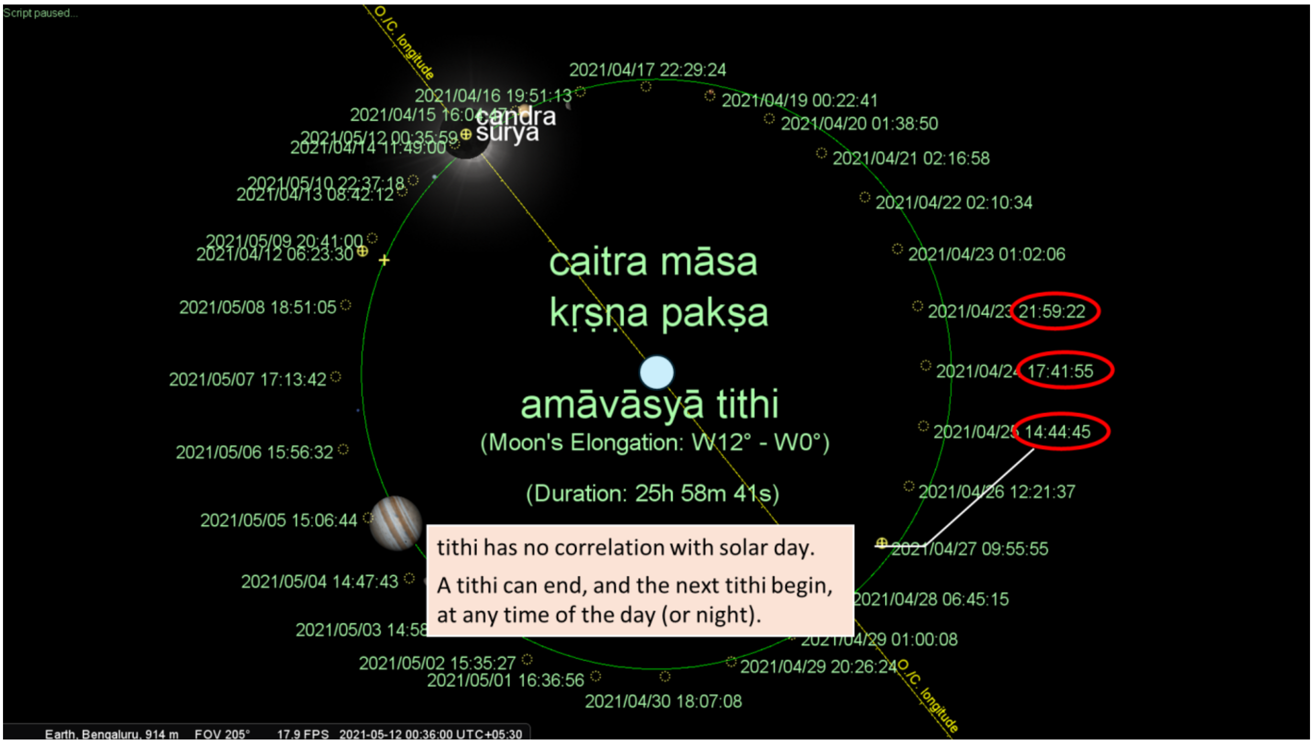


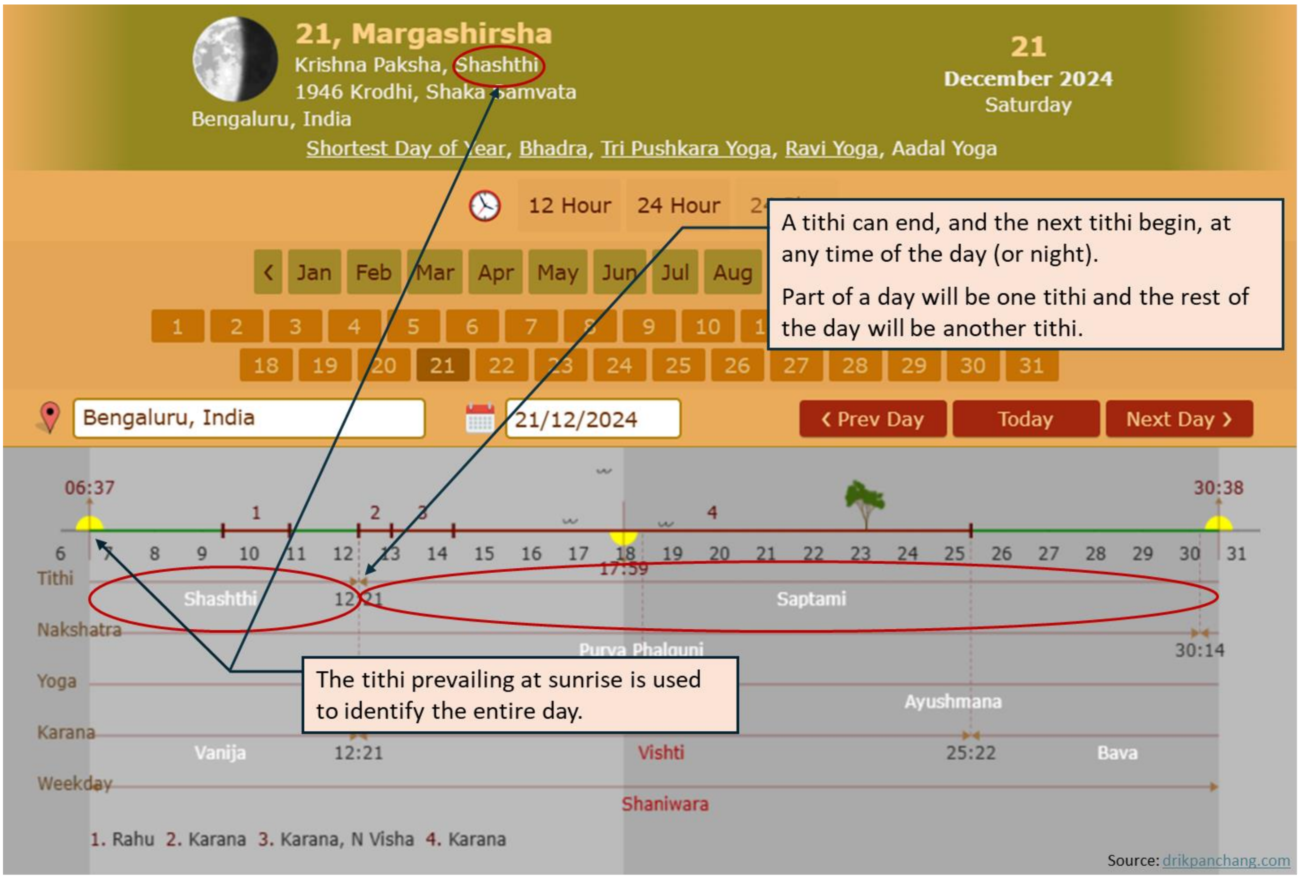
Plate 16 – amāvāsyā tithi ends with the moment of amāvāsyā



tithi has no correlation with solar day.

A tithi can end, and the next tithi begin, at any time of the day (or night).

Plate 17 – tithi is not correlated with solar day



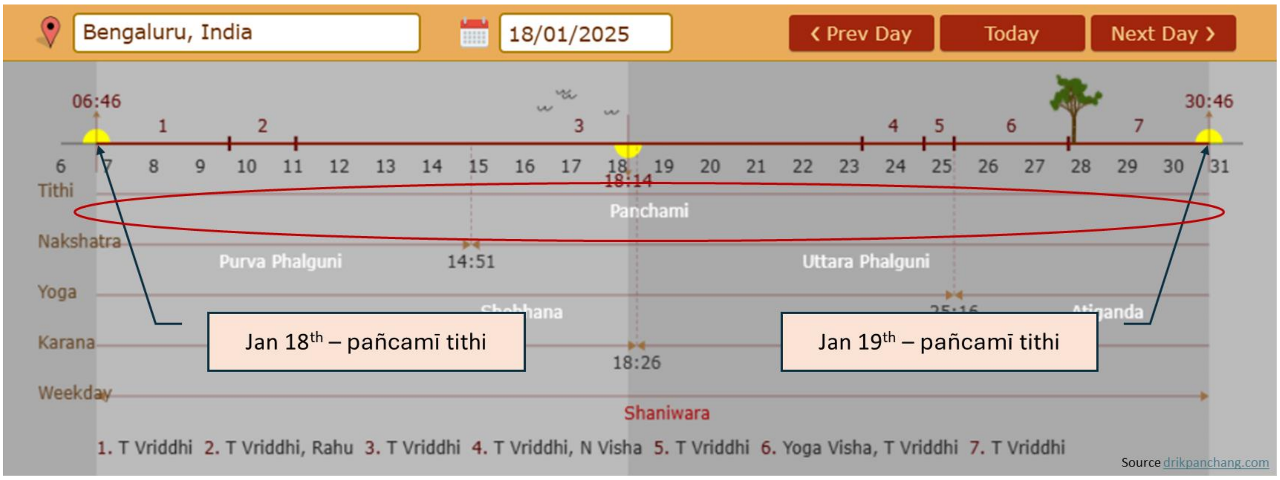
A tithi can end, and the next tithi begin, at any time of the day (or night).

Part of a day will be one tithi and the rest of the day will be another tithi.

The tithi prevailing at sunrise is used to identify the entire day.

Source: drikpanchang.com

Plate 18 – a solar day spans two tithi



Bengaluru, India

18/01/2025

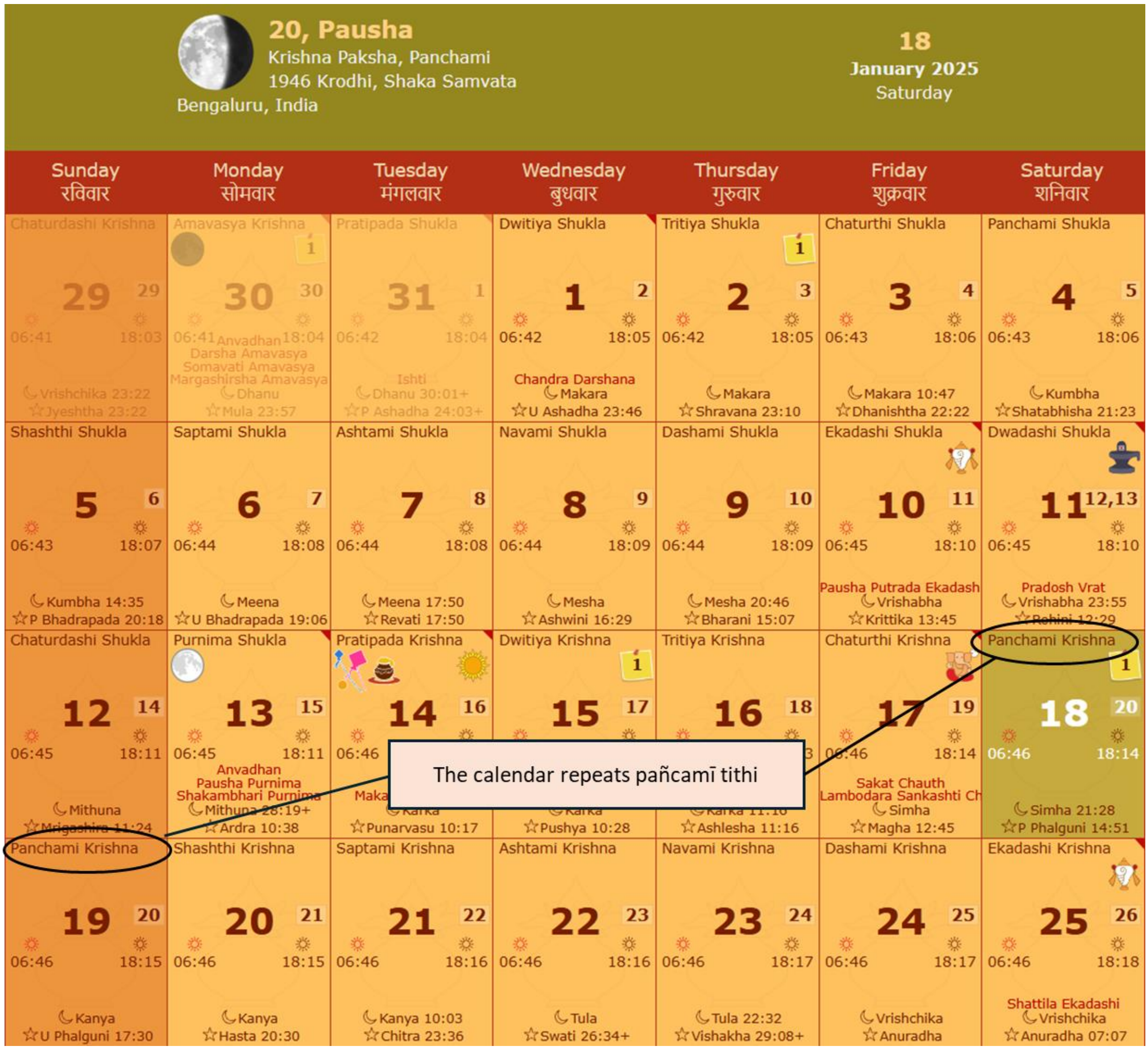
Jan 18th – pañcamī tithi

Jan 19th – pañcamī tithi

1. T Vriddhi 2. T Vriddhi, Rahu 3. T Vriddhi 4. T Vriddhi, N Visha 5. T Vriddhi 6. Yoga Visha, T Vriddhi 7. T Vriddhi

Source drikpanchang.com

Plate 19 – adhika tithi



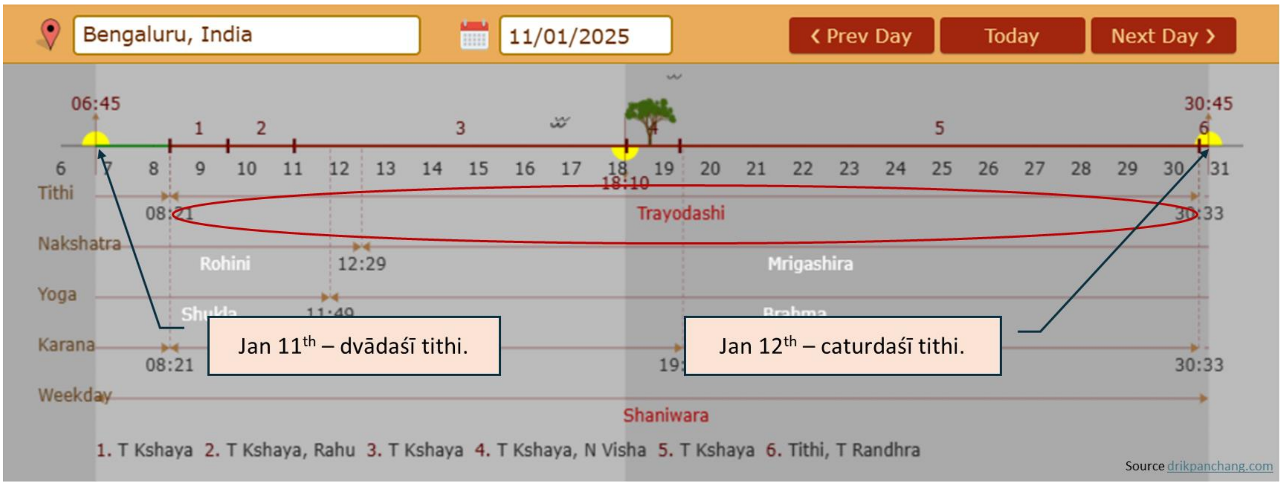
20, Pausha
Krishna Paksha, Panchami
1946 Krodhi, Shaka Samvata
Bengaluru, India

18
January 2025
Saturday

Sunday रविवार	Monday सोमवार	Tuesday मंगलवार	Wednesday बुधवार	Thursday गुरुवार	Friday शुक्रवार	Saturday शनिवार
Chaturdashi Krishna 29 29 06:41 18:03 ☾ Vrishchika 23:22 ☆ Jyeshtha 23:22	Amavasya Krishna 30 30 06:41 Anvadhan 18:04 Darsha Amavasya Somavati Amavasya Margashirsha Amavasya ☾ Dhanu ☆ Mula 23:57	Pratipada Shukla 31 1 06:42 18:04 Ishti ☾ Dhanu 30:01+ ☆ P Ashadha 24:03+	Dwitiya Shukla 1 2 06:42 18:05 Chandra Darshana ☾ Makara ☆ U Ashadha 23:46	Tritiya Shukla 2 3 06:42 18:05 ☾ Makara ☆ Shravana 23:10	Chaturthi Shukla 3 4 06:43 18:06 ☾ Makara 10:47 ☆ Dhanishtha 22:22	Panchami Shukla 4 5 06:43 18:06 ☾ Kumbha ☆ Shatabhisha 21:23
Shashthi Shukla 5 6 06:43 18:07 ☾ Kumbha 14:35 ☆ P Bhadrapada 20:18	Saptami Shukla 6 7 06:44 18:08 ☾ Meena ☆ U Bhadrapada 19:06	Ashtami Shukla 7 8 06:44 18:08 ☾ Meena 17:50 ☆ Revati 17:50	Navami Shukla 8 9 06:44 18:09 ☾ Mesha ☆ Ashwini 16:29	Dashami Shukla 9 10 06:44 18:09 ☾ Mesha 20:46 ☆ Bharani 15:07	Ekadashi Shukla 10 11 06:45 18:10 Pausha Putrada Ekadash ☾ Vrishabha ☆ Krittika 13:45	Dwadashi Shukla 11 12,13 06:45 18:10 Pradosh Vrat ☾ Vrishabha 23:55 ☆ Rohini 12:29
Chaturdashi Shukla 12 14 06:45 18:11 ☾ Mithuna ☆ Mrigashira 11:24	Purnima Shukla 13 15 06:45 18:11 Anvadhan Pausha Purnima Shakambhari Purnima ☾ Mithuna 28:19+ ☆ Ardra 10:38	Pratipada Krishna 14 16 06:46 Maka ☾ Karka ☆ Punarvasu 10:17	Dwitiya Krishna 15 17 ☾ Karka ☆ Pushya 10:28	Tritiya Krishna 16 18 ☾ Karka 11:16 ☆ Ashlesha 11:16	Chaturthi Krishna 17 19 06:46 18:14 Sakat Chauth Lambodara Sankashti Ch ☾ Simha ☆ Magha 12:45	Panchami Krishna 18 20 06:46 18:14 ☾ Simha 21:28 ☆ P Phalguni 14:51
Panchami Krishna 19 20 06:46 18:15 ☾ Kanya ☆ U Phalguni 17:30	Shashthi Krishna 20 21 06:46 18:15 ☾ Kanya ☆ Hasta 20:30	Saptami Krishna 21 22 06:46 18:16 ☾ Kanya 10:03 ☆ Chitra 23:36	Ashtami Krishna 22 23 06:46 18:16 ☾ Tula ☆ Swati 26:34+	Navami Krishna 23 24 06:46 18:17 ☾ Tula 22:32 ☆ Vishakha 29:08+	Dashami Krishna 24 25 06:46 18:17 ☾ Vrishchika ☆ Anuradha	Ekadashi Krishna 25 26 06:46 18:18 Shattila Ekadashi ☾ Vrishchika ☆ Anuradha 07:07

The calendar repeats pañcamī tithi

Plate 20 – adhika tithi is repeated in the Hindu calendar

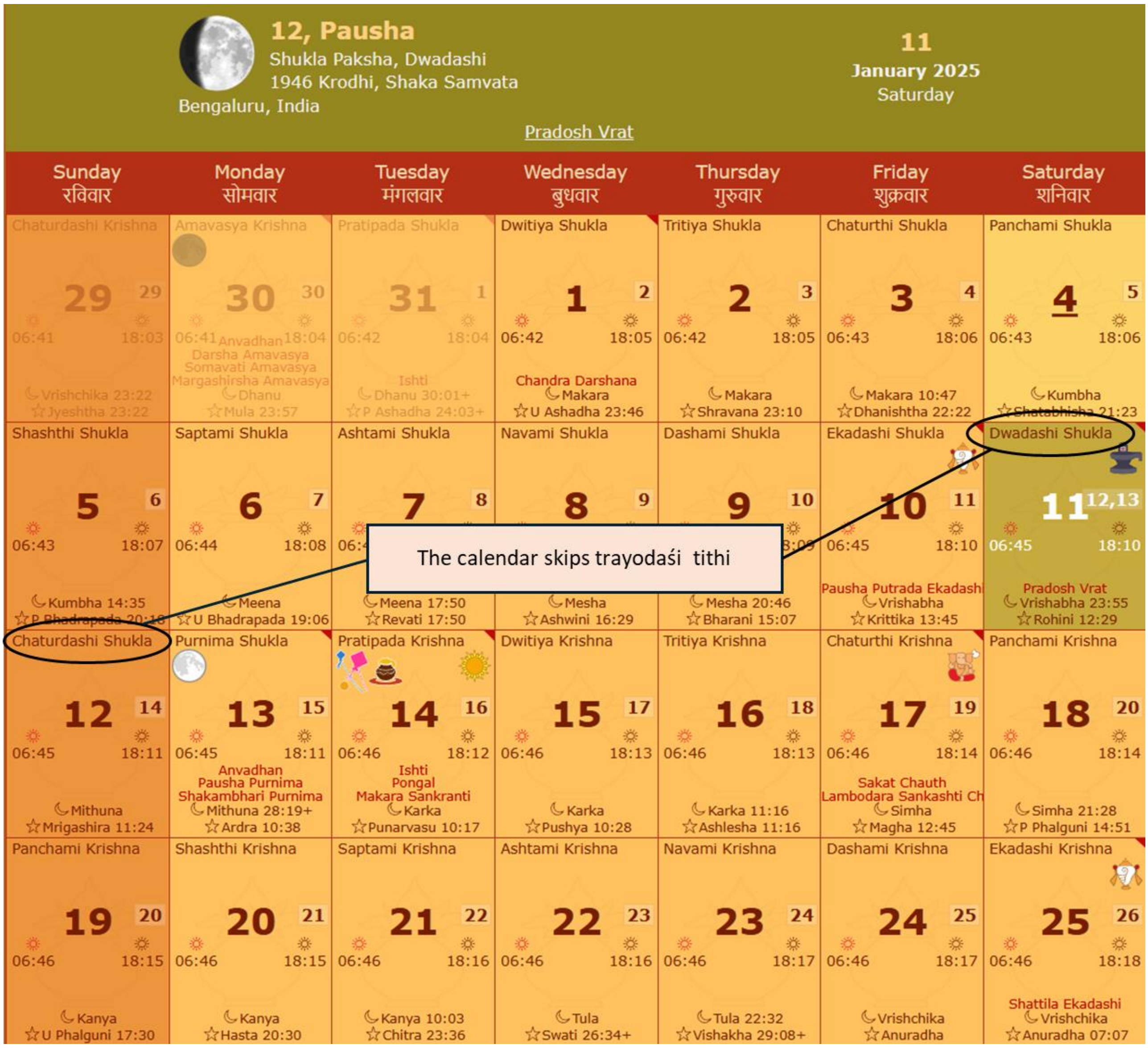


Jan 11th – dvādaśī tithi.

Jan 12th – caturdaśī tithi.

Source drikpanchang.com

Plate 21 – kṣaya tithi


12, Pausha
Shukla Paksha, Dwadashi
1946 Krodhi, Shaka Samvata
Bengaluru, India

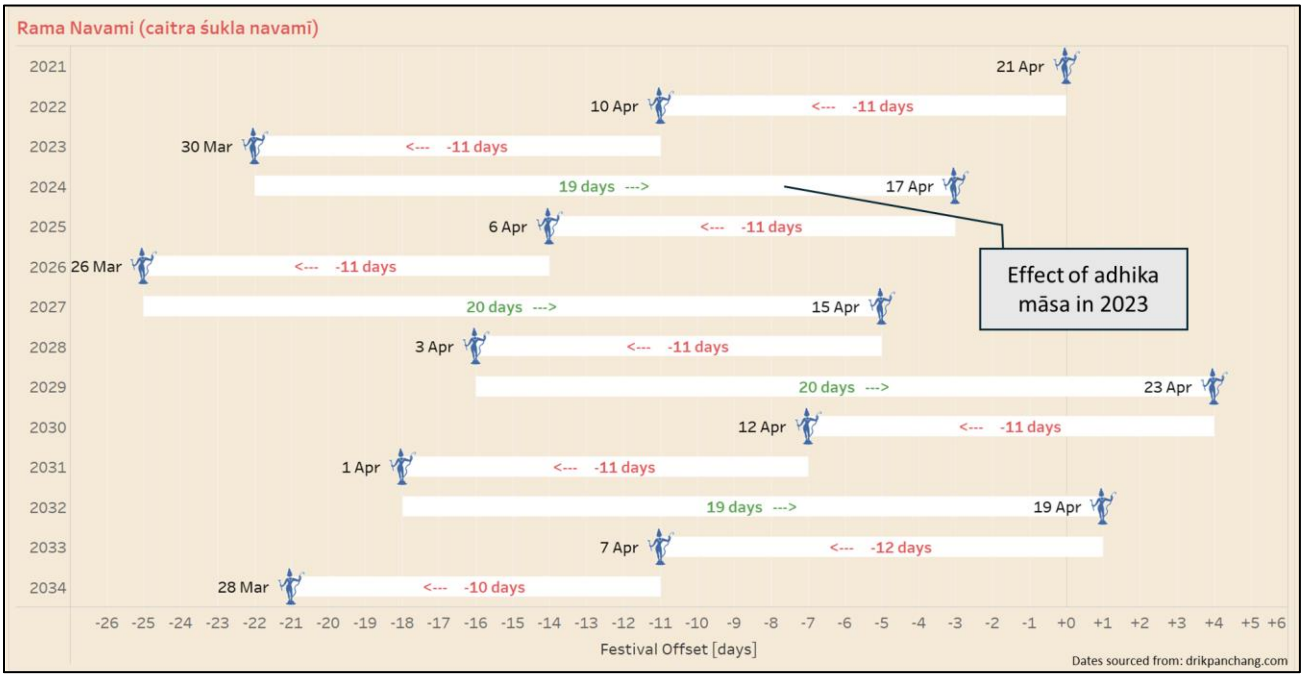
11
January 2025
Saturday

Pradosh Vrat

Sunday रविवार	Monday सोमवार	Tuesday मंगलवार	Wednesday बुधवार	Thursday गुरुवार	Friday शुक्रवार	Saturday शनिवार
Chaturdashi Krishna 29 29 06:41 18:03 Vrishchika 23:22 ☆Jyeshtha 23:22	Amavasya Krishna 30 30 06:41 Anvadhan 18:04 Darsha Amavasya Somavati Amavasya Margashirsha Amavasya Dhanu ☆Mula 23:57	Pratipada Shukla 31 1 06:42 18:04 Ishti Dhanu 30:01+ ☆P Ashadha 24:03+	Dwitiya Shukla 1 2 06:42 18:05 Chandra Darshana Makara ☆U Ashadha 23:46	Tritiya Shukla 2 3 06:42 18:05 Makara ☆Shravana 23:10	Chaturthi Shukla 3 4 06:43 18:06 Makara 10:47 ☆Dhanishtha 22:22	Panchami Shukla 4 5 06:43 18:06 Kumbha ☆Shatabhisha 21:23
Shashthi Shukla 5 6 06:43 18:07 Kumbha 14:35 ☆P Bhadrapada 20:18	Saptami Shukla 6 7 06:44 18:08 Meena ☆U Bhadrapada 19:06	Ashtami Shukla 7 8 06:4 Meena 17:50 ☆Revati 17:50	Navami Shukla 8 9 Mesha ☆Ashwini 16:29	Dashami Shukla 9 10 3:09 Mesha 20:46 ☆Bharani 15:07	Ekadashi Shukla 10 11 06:45 18:10 Pausha Putrada Ekadashi Vrishabha ☆Krittika 13:45	Dwadashi Shukla 11 12,13 06:45 18:10 Pradosh Vrat Vrishabha 23:55 ☆Rohini 12:29
Chaturdashi Shukla 12 14 06:45 18:11 Mithuna ☆Mrigashira 11:24	Purnima Shukla 13 15 06:45 18:11 Anvadhan Pausha Purnima Shakambhari Purnima Mithuna 28:19+ ☆Ardra 10:38	Pratipada Krishna 14 16 06:46 18:12 Ishti Pongal Makara Sankranti Karka ☆Punarvasu 10:17	Dwitiya Krishna 15 17 06:46 18:13 Karka ☆Pushya 10:28	Tritiya Krishna 16 18 06:46 18:13 Karka 11:16 ☆Ashlesha 11:16	Chaturthi Krishna 17 19 06:46 18:14 Sakat Chauth Lambodara Sankashti Ch Simha ☆Magha 12:45	Panchami Krishna 18 20 06:46 18:14 Simha 21:28 ☆P Phalguni 14:51
Panchami Krishna 19 20 06:46 18:15 Kanya ☆U Phalguni 17:30	Shashthi Krishna 20 21 06:46 18:15 Kanya ☆Hasta 20:30	Saptami Krishna 21 22 06:46 18:16 Kanya 10:03 ☆Chitra 23:36	Ashtami Krishna 22 23 06:46 18:16 Tula ☆Swati 26:34+	Navami Krishna 23 24 06:46 18:17 Tula 22:32 ☆Vishakha 29:08+	Dashami Krishna 24 25 06:46 18:17 Vrishchika ☆Anuradha	Ekadashi Krishna 25 26 06:46 18:18 Shattila Ekadashi Vrishchika ☆Anuradha 07:07

The calendar skips trayodaśi tithi

Plate 22 – kṣaya tithi is skipped in the Hindu calendar



Effect of adhika māsa in 2023

Dates sourced from: drikpanchang.com

Plate 23 – Rama Navami on the Gregorian calendar

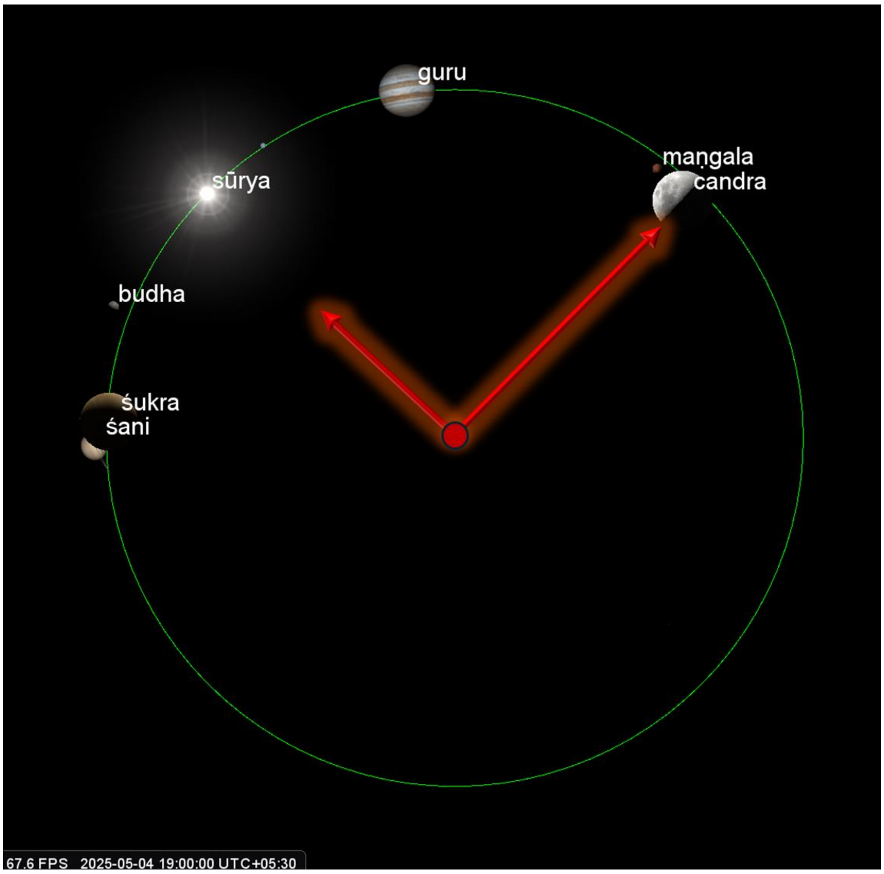


Plate 24 – the celestial clock

Plate 25 – the cosmic dance

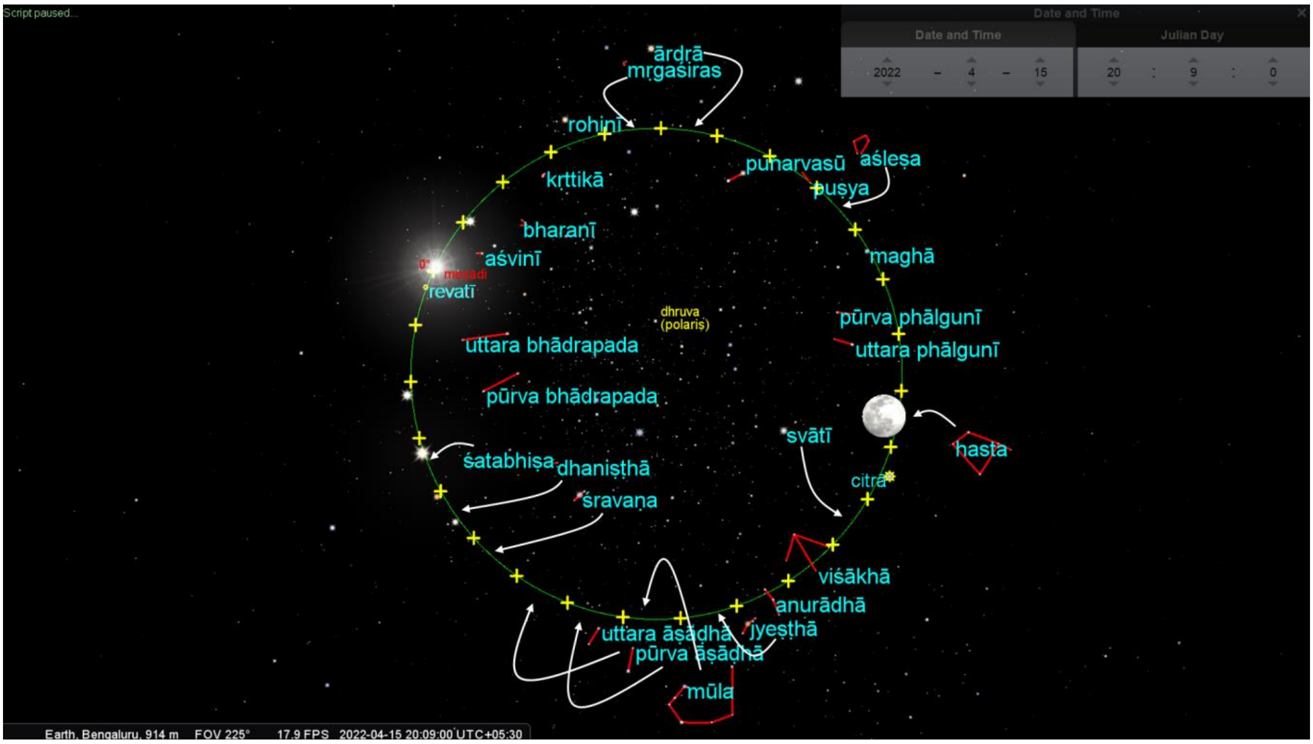
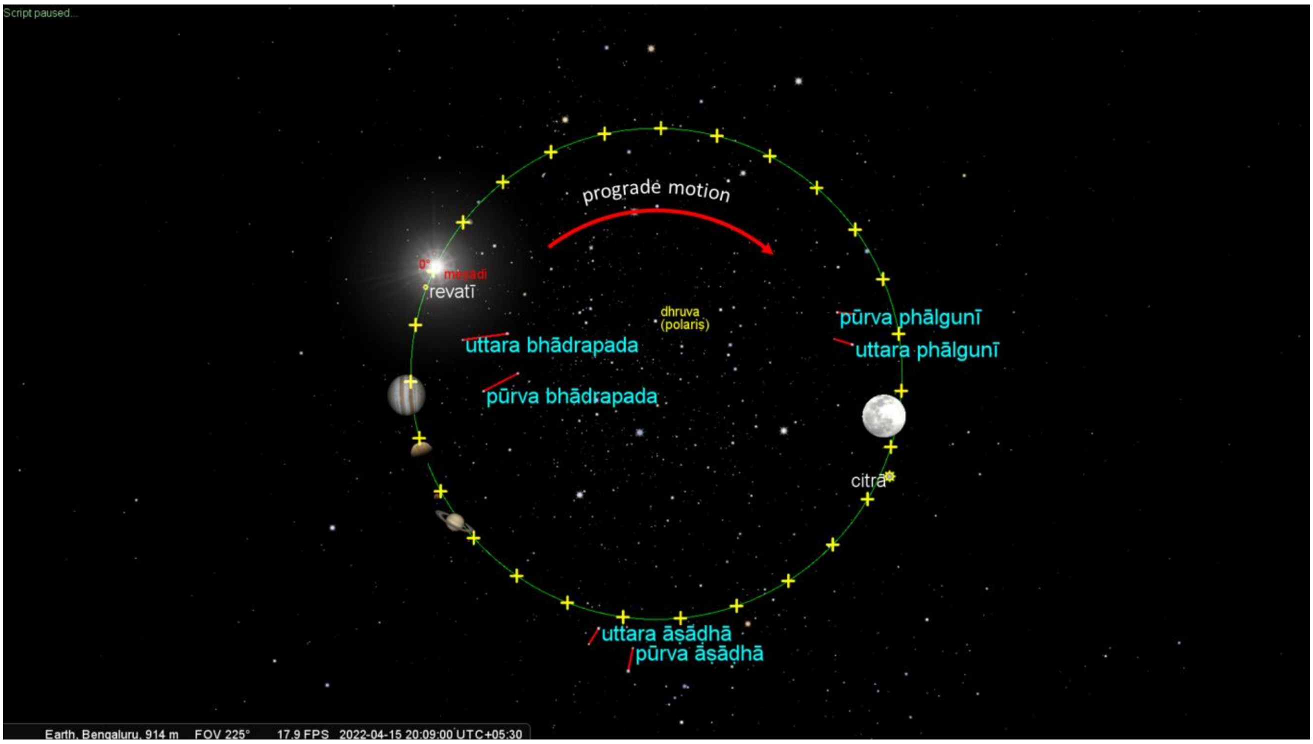
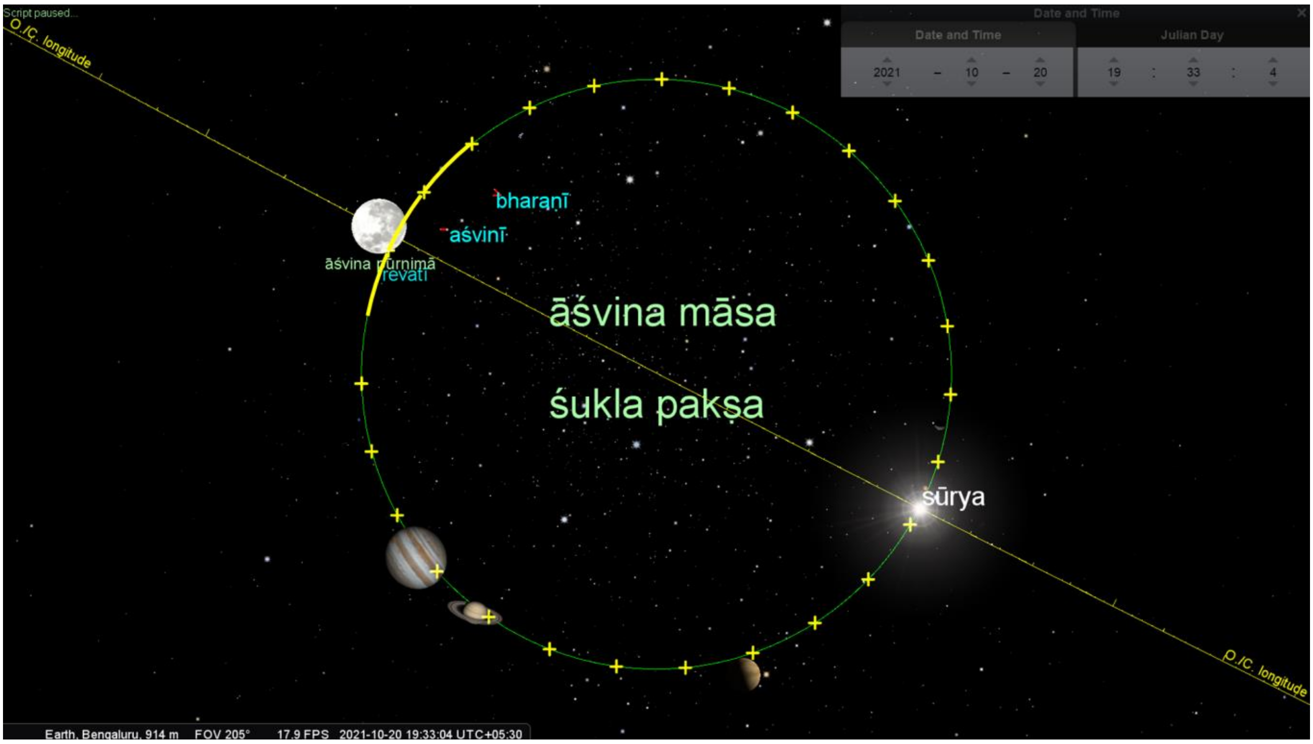


Plate 26 – nakṣatra maṇḍala



Earth, Bengaluru, 914 m FOV 225° 17.9 FPS 2022-04-15 20:09:00 UTC+05:30

Plate 27 – repeating names of nakṣatra



2021 – 10 – 20 19 : 33 : 4

Earth, Bengaluru, 914 m FOV 205° 17.9 FPS 2021-10-20 19:33:04 UTC+05:30

Plate 28 – cāndramāsa derives its name from the nakṣatra near which pūrṇimā occurs

AFTERWORD

This handbook is the result of over a decade and a half of studying, understanding, and internalising the astronomy of the Hindu pañcāṅga. Over the last three years, my efforts have been directed towards spreading this understanding to the general public, initially through a YouTube channel—@Ahargana—and then through lecture demonstrations to live audiences. This handbook is a supplement to the candra māna lecture demonstration.

The twenty-seven episodes of @Ahargana laid the foundation for the lecture demonstrations. The episodes are sequenced in order of conceptual difficulty; they become conceptually more complex as the series progresses. Each episode peels back a layer of the Hindu calendar, enabling understanding of the layers below.

These episodes are built around Stellarium simulations of the orbital movement of the Sun and the Moon, with each episode highlighting one calendric element of the Hindu calendar. The simulations are programmed using the scripting capability of Stellarium. In effect, the Stellarium scripts became the script of each episode and controlled the flow of each episode.

By simulating ancient Hindu calendric concepts using modern-day astronomy software, I have endeavoured to bridge the 1500-year gap that separates the ancient from the modern. The use of modern-day software simulation also confirms that the ancient calendric concepts defined in the Surya Siddhanta remain valid to this day, across a span of a millennium and a half!

In many instances, the act of creating these simulations further broadened and deepened my understanding of the subject, thus proving to me the truth of the adage "If you want to master something, teach it." As I was delivering my very first lecture demonstration to an audience of school teachers, I hit upon a perspective that tied together the celestial geometry of tithi, nakṣatra, and rāśi in a single illustration. That illustration is now a centerpiece of the cāndra māna lecture demonstration (Plate 12). In another instance, the persistent challenge by a secondary school student, "How can you say the Sun moves around the Earth?", forced me to visualise the apparent movement of the Sun more effectively (Plate 4).

While lecture demonstrations are a good means to generate interest in the subject, a real understanding of this subject is possible only through a formal course of learning delivered in academic settings. While a course at an undergraduate level is appropriate, I believe that a substantial portion of this material is accessible even at a secondary school level, thanks to the visual nature of the Stellarium simulations.

The fact that this material sits at the intersection of Hindu culture and Hindu science kindles the curiosity of both parents and students. During a virtual session with the astronomy club of a school, one student messaged on the chat window, "My parents are watching this session along with me!" At the end of the session, another student confessed, "I used to argue with my mother and grandmother that the pañcāṅga is all superstition. They used to insist that it was science, but they were never able to explain that science to me. Now I realise that they were right, and I was wrong."

That pretty much says it all.

While my YouTube episodes relied entirely on Stellarium simulations, it was clear to me that lecture demonstrations needed supplementary material in the form of slides and handouts. When creating this material, I was faced with a choice: should the material be targeted at adults or school children? A little thought convinced me that when it comes to this topic, adults are no different from school children! That made my choice simpler while making my task harder.

Given my background in engineering, it was not easy for me to create material that was suitable for school children and lay adults, as was evident from the first set of slides that I produced. The reviews and feedback from my wife, Malini, and son, Srivatsa (both from non-science backgrounds) were invaluable in refining the material to its final shape. Without their whole-hearted support, my whimsical pursuit of the astronomy of the Hindu calendar would not have made any headway.

My thanks are also due to all the people who attended my lecture demonstrations and provided encouragement and feedback by way of questions and reactions. I hope this handbook answers all their questions and preempts many more that may arise in the future.

S. Kishore Kumar
Bengaluru
June 2025