Orissa Journal of Physics
ISSN 0974-8202
© Orissa Physical Society
Vol. 32, No.2
August 2025
pp. 93-104

On the Charting of the Firmament and Making of an Almanac

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Received: 19 February 2025 Accepted: 05 June 2025 Published 1 August 2025

Abstract: *Tempus Fugit* and the sacred endeavor of Indian *Rishis* are to catch the Time. Sky gazing is the oldest scientific tradition of human civilization and thus the charting of heavens is materialized by mankind. Second, Minute, Hour, Day, Month and Year makes a calendar and thus our ancestors codified time in a systematic and scientific way. Almanac is like a calendar but not a calendar in a true sense and it is something more than a calendar. Indian almanac is known as *Panchanga* or *Panji* and it is the most scientific charting of the firmament in this world and people still believe that it described the other world also. Indian almanac or *Panchanga* has five limbs, as the name suggests. These five aspects are *Vara, Tithi, Nakshyatra, Yoga and Karana.* The first three are associated with the time measurement using astronomical references and last two are related with social-cultural practice of ancient *Hindu*. Making of the *Vara* is related with the motion of astronomical objects in the solar system and is synonymous with the Solar day. Making of the *Tithi* is related with the motion of the Moon and is synonymous with the Lunar day. Making of the *Nakshyatra* is associated with relative position of specific stars in the sky, when they are observed from Earth. How the heavens set in order and ancient Indian reckoning of Sun, the Planets, and Stars Indian almanac or *Panchanga* is done is important historical research for an astronomer. The making of *Vara, Tithi, Nakshyatra* and charting of firmament is reported in this communication.

Key words: Almanac, firmament, astronomy

1. INTRODUCTION

The silent chronicle, firmament marks the passage of day, month and year, as Sun, Moon, other planets, stars trace their ordained paths, real or apparent, and mankind witness cosmic order in their calendar. The most scientific and systematic calendar exists still today is in form of Indian Almanac or *Panchanga* or *Panji*. In this communication you can find how Indian almanac is based upon systematic observation of the positions and motions of the Sun, planets, specific stars, and constellations across the celestial sphere. Ancient Indian astronomers determined these parameters using carefully designed high precision handmade observational instruments and models like *Eka Kakshya Gola Yantra, Bahu Kakshya Gola Yantra, Chakra Jasta Yantra, Graha Chakra Jasti, Golardha Yantra, Mana Yantra, Mapa Yantra, Kapala Yantra, Swayamvaha Yantra,* and

well defined mathematical and geometrical methods. [1-3] The estimated astronomical constants and ephemerides demonstrate high degree of agreement with the values obtained from modern observations using advanced telescopic and computational techniques. [3-5] Indian almanac arises from celestial testimony and this article recounts the methodical making of the Indian almanac or *Panchanga* or *Panji* through disciplined observation of sky.

Indian astronomical treatises, *Siddhantas*, are classic texts on astronomy and astrophysics. Both theoretical and experimental research is embedded in these texts. The earlier *Siddhantas* includes, *Paitamaha Siddhanta, Vasistha Siddhanta, Romaka Siddhanta, Paulisa Siddhanta, Surya Siddhanta.* These five *Siddhantas* are known as *Apaurnseya* in Hindu tradition. Besides, we have with us today, *Aryabhattiyam* by *Maharshi Aryabhatta* of Pataliputra, *Pachasiddhantika* by *Maharshi Varahamihira* of Ujjain, *Siddhanta Siromani* by *Maharshi Bhaskar-II (Bhaskaracharya)* of *Vijjadavida*, *Bhaswati* by *Maharshi Satananda*, *Siddhanta Darpan* by *Samanta Chandrasekhar Harichandan Mohapatra (Pathani Samanta*). The most important one out of all these is *Surya Siddhanta* believed to be told by *Surya Deva* to *Maya*. The *Surya Siddhanta* is available with us and is having 500 verses divided into 14 chapters. This *Siddhanta* was first published in English by Rev. E. Burgess, in 1860 and republished by the Calcutta University under the editorship of P. L. Gangooly. The *Surya Siddhanta* is believed to be most authentic and accurate. The development of theoretical and experimental astronomy and astrology during the *Siddhantic* tradition in India is praiseworthy. [5] Indian almanac has five aspects and these are *Vara, Tithi, Nakshyatra, Yoga and Karana.* The first three are associated with the time measurement using astronomical references. Making of the *Tithi* is related with the motion of the Moon and is synonymous with the Lunar day. Making of the *Nakshyatra* is associated with relative position of specific stars in the sky, when they are observed from Earth.

2. MATERIALS AND METHODS

Original Sanskrit texts are primarily studied in this research work. [1, 6-8] The interpretation by modern scholars is taken into account to understand the accuracy of estimated astronomical constants and ephemerides depicted in these ancient Sanskrit texts. [2-5] Earlier texts on Indian almanac are also studied and used during interpretation of concepts. [9-10] Indian Almanac or *Panchanga* or *Panji*, as the name suggests (*Pancha* (Five) + *Anga* (aspects or limbs)) is having five aspects, namely, *Vara, Tithi, Nakshyatra, Yoga, Karana*. These five aspects

club together to constitute *Panchanga*. *Panchanga,* not only picturize time in a systematic and scientific way, but also affects our socio-cultural life in a positive way. These five aspects may be perceived to be five limbs of time, if at all personified. Sky gazing and mathematical calculations there in, specifies the specific position of some astronomical objects used by *Panjikar* (he who makes the *Panchanga*) and their dynamics in celestial sphere over our head and thus charting of the firmament is done. Occurrence of some complicated phenomena like eclipse and the correct prediction of *Panjikar* in this regard is a solid proof of the accuracy of the measurement of position and dynamics of astronomical objects like planets and stars by him/her. At present around 250 independent *Panchanga* are being published in Indian sub-continent. The philosophy and science used by *Panjikar* to make *Panchanga* is very much similar. *Panchanga*, is basically of two types: *Druksiddha* and *Drushya*. *Druksiddha Panchanga* is the purest form and is made using the principles enumerated in the *arsha* text *Surya Siddhanta*. *Drushya Panchanga* not only uses the astronomical observations made by the latter scholars like *Varahamihir, Bhaskar-II, Shatananda, Samanta Chandrasekhar*, modern astronomers across the globe but also the classic texts like *Pancha Siddhantika, Siddhanta Siromani, Bhaswati, Siddhanta Darpan* etc. for making of the *Panchanga.* For astronomical measurements a number of classic texts are being referred, to name a few, *Surya Siddhanta, Ketaki, Grahalaghab* etc. The writer of the classic astronomical text *Siddhanta Tatvaviveka*, *Acharya Kamalakar Bhata* writes, "Astronomical results are demonstrable only when experimental observations and theoretical calculations are identical". Looking at the methods and methodology used by the *Panjikar*, and the diversity so involved, making a *Panchanga* is a commendable work unlike making the modern calendar. The common practice in making a *Panchanga* is of two types: one that takes the current positional values of sun and moon independently and by using interpolation method and thus the different aspects of *Panchanga,* is evaluated. The other one is using the readymade table and chart for getting the values and making the *Panchanga* thereafter.

3. RESULTS AND DISCUSSION

Indian socio-cultural life has a rich heritage. Proper and accurate timekeeping shaped our traditional ethos. Tracking and predicting the position and motion of astronomical bodies are very much essential in order to keep time, in order to fix moments and day of socio-cultural rituals like marriage, thread ceremony, offering in fire, housewarming and so on. Indian Almanac or *Panchanga* or *Panji* is a collective term for luni-solar calendar traditionally used

by practiced Hindus and Nakshyatra and specific fixed constellations are also taken into account therein.

The moon cycle and solar cycle is being used for estimating all the aspects of *Panchanga* except *Vara*.

3.1 ***Varadianayan*** (Making of a *Vara*):

In an Indian almanac, the nomenclature of *vara* goes like this- *Ravi, Soma or Chandra, Mangal or Bhauma, Budha, Guru or Brihaspati, Shukra and Shani*. These *vara* or days are named after different *Graha* in astronomy and astrology. In Indian astronomy, *Ravi* or *Surya* or Sun, *Soma* or *Chandra* or Moon, *Mangal* or *Bhauma* or Mars, *Budha* or Mercury, *Guru* or *Brihaspati* or Jupiter, *Shukra* or Venus, *Shani* or Saturn are termed as Graha (roughly we can say planets).

As per orbit number depicted in the classic astronomical text *Surya Siddhanta* the ruler of the *vara* (day) is decided by a certain specific principle and the said *vara* (day) is named after the ruler of that day. It was believed by astronomers in ancient India that at the time of creation, there is light. Sun or *Surya* symbolizes light. The first *vara* (day) is named after *Ravi* or *Surya* or Sun and the last one named after *Shani* or Saturn. From *Shani vara* onwards the immediate next *vara* (day), is named after *the fourth Graha* downward in the *Kakshyakrama* (orbit number). It is said that this planet will be the ruler of that day. At the time of creation Sun rises, hence the first *vara (day)* is named after him and *Ravi* (Sun) is the lord of first *hora* on that very Sunday. One *hora* is one twenty fourth of a *vara* (day). The next planet downward in the *Kakshyakram* (orbit Number) i.e. *Mangala* (Mars) is the lord of next *hora* and it goes like this. So, you can see that *Soma* or *Chandra* or Moon is the lord of 25th hora or the first hora of the next *vara* (day). The first planet in the orbit number depicted in the Surya Siddhanta is Saturn (Son of Sun) and the rest are shown graphically in fig 01. In Surya Siddhanta it is written that-

Mandādadhah krameṇ syuchaturtha divasadipā ।

Varshādhipatayastadrat trutiyah parikirtitah ॥ 78 ॥

Urdhwakramena Shashino māsanamadhipāh ।

Horeshah Suryatanayahdadhoadhah kramashstatha ॥ 79 ॥

-(*Surya Siddhanta*; *Bhugoladhyayah*; 78-79)

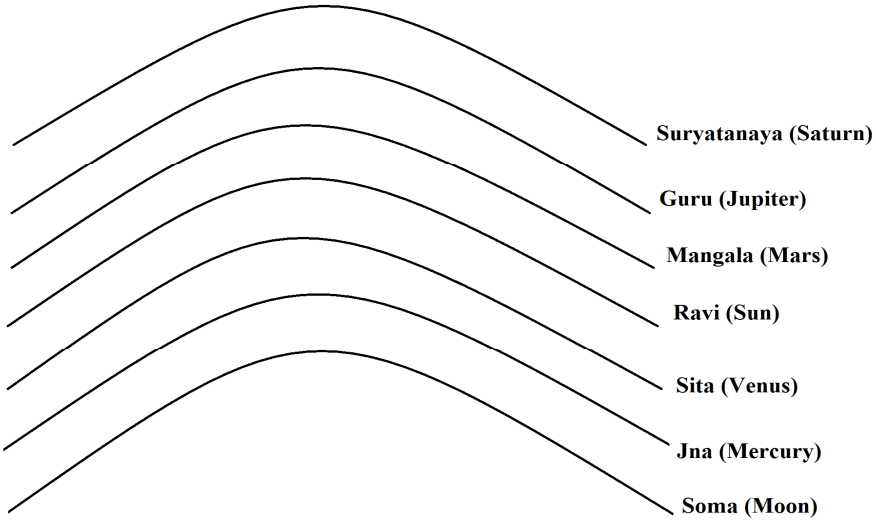

Fig 01: *Kakshyakram* (orbit Number) described in the *Surya Siddhanta*

It is worth noting that the orbit number provided here for the making of a day, may not be confused with orbit number of different planets in the order of their distance from Sun. *Samanta Chandrasekhar* writes about the making of orbit number as described in *Surya Siddhanta* as follows-

Dināvdaho ramaseshajnanayanyagradwisthiti ।

Dastatatralpgatijah sthapyaurddhwehapyadhapunah ॥ 103॥

Vahubhukti kalakheta itathamesha tramobhaveta ।

Surya Siddhante-mandamarejyabhuputra Suryashukremdujemdavah ॥ 104॥

-(*Siddhanta Darpana*; Chapter - 19; 103-104)

The slower moving planet will be above and the other is being placed downward in the series taking their speed (mean motion) into consideration. So, in *Surya Siddhanta*, the planets are arranged from above to downward in the increase order of their mean speed. Several scholars have estimated mean motion of planets from the original text written by Indian astronomers. A scholar has taken the values from the work of *Brahmagupta* (628 AD) and compared it with the modern values. Their values are almost same with modern values and are shown in table 01. [11]

Table 01: Mean speed of a *Graha*

Planets	***Brahmagupta*** (Mean motion) ° ′ ″
Saturn	0/02/0
Jupiter	0/04/59
Mars	0/31/26
Sun	0/59/8
Venus	1/36/7
Mercury	4/05/32
Moon	13/10/34

From table 01, it is clear that the orbit number described in the *Surya Siddhanta* is accurate and it is traced in momentum phase space. So, *Suryatanaya* or son of the Sun or *Shani* or Saturn is placed in first position in the orbit number. The rest of the planets are placed as follows, *Guru* or Jupiter, *Mangala* or Mars, *Ravi* or Sun, *Sita* or *Shukra* or Venus, *Jna* or *Buddha* or Mercury, *Soma* or *Chandra* or Moon.

3.2 *Tithyadianayan* (Making of a *Tithi*):

The second aspect of an Indian almanac is *Tithi*. It is the basic constituent of a lunar calendar. In the *Surya Siddhanta*, it is written that

Chāndramānam Tithimānascha –

Arkādavinissrutah prachim yadyatyaharah Shashi ।

Tachchandramanamshaistu jneya dwadashabhististhih ॥ 12॥

-(*Surya Siddhanta*; *Mānāddhyaya*; 12)

The conjunction of Sun and Moon over the sky ends at a certain point of time, and Moon moves eastward from the Sun. The moment conjunction of Sun and Moon is over, the first *Tithi* in a lunar month starts, and it ends at the moment moon moved 12^0 eastward – described in the *Surya Siddhanta*. It is worth noting that this *Tithi* is called *Pratipada*. The second *Tithi,* then started and will be over when moon moves another 12^0 eastwards, or moves 24^0 eastwards from the time at which conjunction of Sun and Moon is over. This is the second *Tithi* called *Dwitiya*. And this goes on. The pictorial representation of Moon motion as seen from Earth's surface is shown in fig 02. The author acknowledges internet sources to make this figure. There are 30 *Tithis* in a lunar month or synodic month. The last *Tithi* called *Amavashya* or no moon day. It starts when conjunction of Sun and Moon starts and ends when this conjunction is over. From

Pratipada to *Amavashya* is one lunar month having 30 *Tithis*. The lunar month consists of 29.5306 solar days. It is the time taken by moon for one complete rotation around Earth.

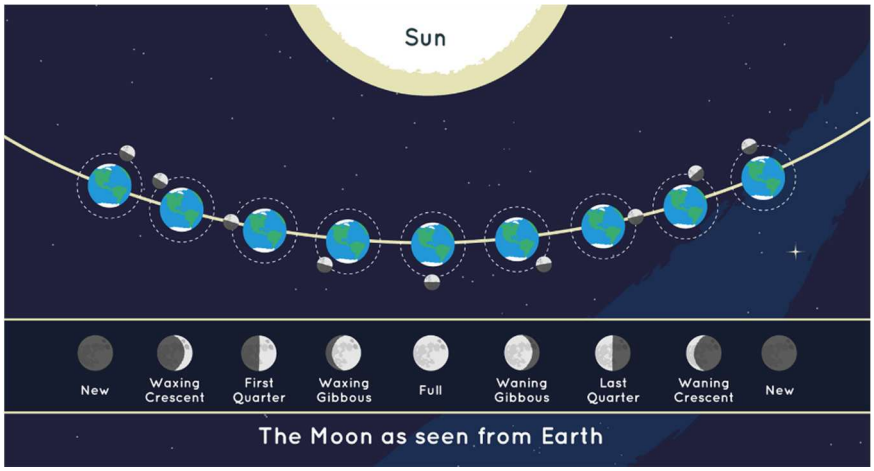

Fig 02: Moon motion as seen from Earth's surface (Phases of moon)

Tithi is being evaluated if we know the *Chandra Spasta* (Longitude of Moon) and *Surya Spasta* (Longitude of Sun). In *Panchanga* these two values are given at the beginning of a month. If longitude of Sun (*Surya Spasta)* is S_0 and longitude of Moon (*Chandra Spasta*) is M_0, then the *Tithi* shall be evaluated using the formula

$$\mathbf{(M_0 - S_0)/12 = Q + R} \qquad \mathbf{(1)}$$

The quotient (Q) being the *Gata Tithi* (Previous lunar day). (Quotient + 1) will be the current *Tithi* (lunar day). Here the difference in the longitude of Moon and Sun is the dividend and 12 is the divisor. It is worth noting that 12^0 angular displacements eastward constitute one *Tithi*.

Suppose at a particular instance the longitude of Sun is 19.25^0 and that of moon is 110.23^0. So, here M_0 is 110.23^0 and S_0 is 19.25^0.

So, $(110.23^0 - 19.25^0)/12 = \mathbf{7} + 0.58$

So, *Gata Tithi* (Previous lunar day) is *Panchami* (5th lunar day) and the current T*ithi* is *Sashthi* (Sixth lunar day). Lunar month is sub-divided into two halves – *Krishna Pakshya* covering the period of full moon to new moon and popularly termed as *vādi*, and *Shukla Pakshya* covering the period from new moon to full moon and termed as *sudi*. Twelve lunar months constitutes one lunar

year (*Chandra Varsha*). So, one regular lunar year will be around 354.367055 days (~ *360 Tithi*). So, the lunar year slides back on the solar scale each year by about 11 days. So, there is some corrections in a scientific and systematic manner. Intercalary months or *Mala Māsas* feature have been introduced in a lunar calendar or almanac. The 19th year lunar month cycle is having seven *Mala Māsa* in it. [9] In a *Mala Māsa* there shall be no *Sankranti* and it is also known as *Asankranti Māsa*. After thirty-two (32) solar months usually a *Mala Māsa* (intercalary months) falls and in this month, there are two moments of new moon in that solar month and the lunar intercalary month (*Mala Māsa*) begins from the first new moon in the said month. In the year where a *Kshyaya Māsa* (decayed month) falls there shall be two *Mala Māsa* (intercalary months) in that year. Introducing *Mala Māsa* and *Kshyaya Māsa* in an Indian almanac synchronizes astronomical solar year and lunar one.

Most of the socio-cultural and religious holidays in the government calendar are regulated by lunar calendar. This may be because, Indians have used lunar calendar for their day-to-day life. So, lunar calendar is an important part and continue to play very important part as we continue to keep our connection with the past and with our cherished tradition.

3.3 ***Nakshyatradianayan*** (Making of a *Nakshyatra*):

We know that Moon orbits the Earth and it appears so as we observe the Moon from Earth's surface. If we observe the moon motion in a clear sky at night, it appears to move through the sky and pass in front of many background stars and constellations. Some specific stars and constellations are taken into account by Indian astronomers to chart the firmament by making the wheels of stars (*Bhachakra*). When this circular path of Moon is divided into Twenty-seven (27) equal parts, twenty-seven constellations are taken for reference and these twenty-seven constellations are termed as *Nakshyatras*. When this circular path of Moon is divided into Twenty-seven (27) equal parts, twenty-seven constellations are taken for reference and these twenty-seven constellations are termed as *Nakshyatras*. Actually, twenty-eight *Nakshyatras* are there in the sky, but *Abhijit* was usually not considered. Similarly, Sun appears to orbits the Earth as we observe the Sun from Earth's surface. When this circular path of Sun is divided into twelve (12) equal parts, twelve constellations are taken for reference and these twelve constellations are termed as *Rashi (Zodiac)*. So, the wheel of stars (*Bhachakra*) consists of twenty-seven (27) constellations (*Nakshyatras*). These *Nakshyatras* or constellations of stars are *Ashwini, Bharani, Krittika,*

Rohini, Mrigashira, Ardra, Punarvasu, Pushya, Ashlesha, Magha, Purva Phalguni, Uttara Phalguni, Hasta, Chitra, Swati, Vishakha, Anuradha, Jyeshtha, Mula, Purva Ashadha, Uttara Ashadha, Shravana, Dhanishta, Shatabhisha, Purva Bhadrapada, Uttara Bhadrapada, and Revati. These twenty-seven small constellations are taken into reference for making of a lunar month, whereas twelve big constellations are taken into consideration for making of the solar month. These twelve constellations that makes solar months are pictorially shown in fig 03. The author acknowledges internet sources to make this figure. These twelve constellations are also known as *Rashi* and these are as follows- *Mesha* (Aries), *Brusha* (Taurus), *Mithuna* (Gemini), *Cancer* (Karka), *Simha* (Leo), *Kanya* (Virgo), *Tula* (Libra), *Vrichhak* (Scorpius), *Dhanu* (Sagittarius), *Makar* (Capricornus), *Kumbha* (Aquarius), *Mina* (Pisces).

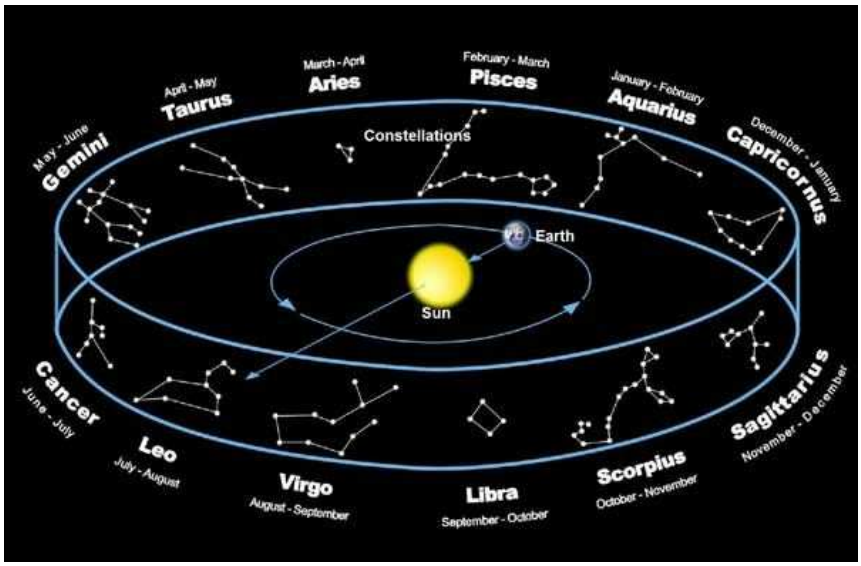

Fig 03: Pictorial representation of twelve constellations in celestial sphere.

In the *Surya Siddhanta*, it is written that

Nakshyatramanam-

Bhachakrabhramanam nityam nākshyatram dinamuchyate ।

Nakshyatranamnā māsāstu jneyāh parvāntayogatah ॥ 15॥

Kartikyadishu samyoge krutikādi dwyam dwyayam ।

Antyopāntyo panchchamashch tridha māsatrayam smrutam ॥ 16॥

-(*Surya Siddhanta*; *Mānāddhyaya*; 15-16)

If in the full moon day (*Purnima Tithi*) of a lunar month (*Chandra Māsa*), the moon is having transit with *Krittika* or *Rohini* then the said month shall be called as *Kārtika*. All other lunar months thereafter is named after certain *Nakshyatra* (lunar constellation) depending upon lunar transit with it or its adjacent *Nakshyatra* (lunar constellation) in the full moon day, except the last, one before last and the fifth month. Thus, the names of different months are *Kārtika*, *Mārgasirsha*, *Pausha*, *Māgha*, *Phālgun* (lunar transit with *Purva-Phalguni*, *Uttara-Phalguni* or *Hasta*), *Chaitra*, *Vaishākha*, *Jyestha*, *Āshādha*, *Shrāvana*, *Bhādrapada* (*Shatabhisha*, *Purva- Bhādrapada*, *Uttar-Bhādrapada*), Āshwina (lunar transit with *Revati*, *Ashwini*, *Bharani*).

So, the wheels of stars (*Bhachakra*) are divided into Twenty-seven (27) equal parts. This division is based on the Moon's sidereal month, which is about 27.322 days long. Since the Moon takes this much time to complete one orbit around Earth with respect to the stars, it spends roughly one day in each *Nakshyatra*.

The full circle of the sky is 360 degrees, and it is divided into 27 Nakshatras. So, each Nakshatra spans:

$360°/27 \approx 13°20'$

This means every *Nakshyatra* occupies 13 degrees and 20 minutes of arc in the sky along the ecliptic—the apparent path of the Moon and planets.

The principle of estimation of *Nakshyatra* is somehow similar to that of a *Tithi*. One complete rotation of the wheel of stars (*Bhachakra*) in the sky (heaven) is known as one *Nakshyatra Dina* (Sidereal Day). The time between two consecutive transits of the beginning point of any constellation in the celestial sphere is one *Nakshyatra Dina* (Sidereal Day). Astronomically, a sidereal day is the time taken by any distant star to return to the same position in the sky. The length of the sidereal day (T_s) can be calculated using the formula

$$\mathbf{T_s = (360°/361°) \times T_{so} \approx 23.\ 9345\ hours} \qquad \mathbf{(2)}$$

Where T_{so} is the length of a solar day.

It is worth noting that while the Earth is rotating, it is also moving along its orbit around the Sun. Hence, Earth rotates 360° on its axis plus about 1° angular distance covered in its orbit around the Sun. So, net angular displacement is 361° which is in the denominator. The *Nakshyatra dina* (sideral day) is the time period takes for a distance star to return to the same position in the sky. Obviously, it is the apparent motion of a star as seen from Earth's surface. It is about 23 hours 56

minutes and 4.1 seconds. Modern day astronomers use sideral time to point telescopes towards astronomical objects like stars, constellations, galaxies, and other deep sky objects. A sideral year is around 365.2564 days and is about 20 minutes longer than a tropical year.

4. CONCLUSION

Indian *Rishis* and scientists formulated five aspects of Indian traditional almanac through scientific and systematic observation of specific astronomical objects like, the Sun in its daily course, planets in their measured wanderings, and the stars in their fixed configurations. The first three aspects of Indian almanac, what we call *Panchanga* or *Panji* – reflects a rigorous synthesis of celestial mechanics and calendrical computation, is a reflection of scientific observation and geometry. The accurate agreement between these traditional Indian measurements and modern telescopic results arrests scientific integrity of Indian knowledge tradition. The results of these charting of the firmament resulted in accurate prediction of complex astronomical phenomena like solar and lunar eclipse. It is worth noting that an Indian almanac and its aspects like *Vara, Tithi, Nakshyatra, Yoga and Karana* have served as a guiding framework for socio-cultural rhythms, binding human activity to ordered motions of the heavens and affirming a sacred dialogue between astronomical knowledge and lived experience.

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