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Development of Pañcanga from vedic times upto the present

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Abstract. Hindu calendar *Pañcanga* evolved gradually from vedic times of remote antiquity with the continuous developments of solar and lunar kinematics and dynamical theories upto the present times. Here we discuss the earliest observational studies which led to the emergence of *Vedanga Jyotisa* (V.J.) calender of five years yaga system. The calender of remote antiquity had only one element (anga) the 'Tithi'. Later other elements like naksatra etc got added resulting into *Pañcanga* having five elements.

V.J. calender was based on mean motions. Sinusoidal equation of centre evolved gradually with the rise of theoretical astronomy. *Sūrya Siddhānta* (S.S.) school had the 1st equations of centre for sun and moon which are hybird of actual 1st equation of centre and some perturbative terms, but other terms like eviction variation, annual variation etc. too evolved in Indian tradition under unique observational circumstances. These developments in pre-Newtonian and post-Newtonian periods are discussed in detail comparing with the parallel developments in the west.

The acceptability of the modern *Dṛk* school (which uses all gravitational lunar perturbation terms) is discussed in details. The controversies regarding *Ayanānsá* (precession and decision making about religious festivals are discussed, especially the case of *kṣaya māsa* is elaborated in detail.

It is proved that according to *Dṛk* school the maxima and minima of tithis are 67 *gatīs* and 50 *gatīs* respectively and these depend upon the number of tithis, while according to S. S. the minimum of all tithis is 54g and maximum 65g irrespective of the number of tithis.

The present *Pañcangas* use most advanced Solar and Lunar dynamical theories. Other religious calendars of the world use more or less only the mean motion parameters. Hindus had the scientific bases for all religious observances and thus promoted the cause of development in Solar and Lunar theory and even today accepted the most advanced accurate formulae for computations of *Pañcanga* elements.

Key words : *Pañcangas* - hindu calendar, intercalary and kṣaya month - and hindu religious festivities.

1. Introduction

The hindu calendar has a long history of developments over many centuries. (Sharma 1985). In the remote antiquitic Rigveda strata, Moon is said to be the maker of months "Cȧndraḥ Māsakṛt". Later Sun is said to be the maker "Sūryah Māsakṛt". In the case of the purely lunar calendar, the seasons were found to go out of consonance. Thus the necessity for adjustments of the two calendars was felt. In fact the lunar calendar got adopted in remote antiquity and thus it acquired religious sanctity. Under these conditions, it could be dispensed with. The solar months which determined the seasons had to be used as standards for the seasonal festivities. Every year the Lunar months were found to recede back by 10 or 11 days. Thus within three years or so, there had to be interpolated extra lunar month (the intercalary month) which adjusted the festivities back to their respective Seasons. Hence the lunisolar astronomical parameters had to be determined with the best possible accuracy. The motions of Sun and Moon both had to be studied for synchronisation of the two calendars and in order to avoid discretionary adhoc choices of the intercalaries, foolproof algorithm had to be evolved. These attempts prompted the developments of observational Astronomy. It may be remarked that development of vedāṅga jyotiṣa took thousands of years. The earliest developments of remote antiquity are out of scope of this paper. There were times when spring equinox was at mṛigasirṣa (400 B.C) and later around 2400 B.C. it shifted to Kṛttikās at the time of yajurvediya satapatha Brāmaṇa.

These periods need exhaustive investigations. The earliest Hindu calendar had only one element the "Tithi" later evolved other elements nakṣatra yoga Karaṇa and vāra. Vedāṅga Jyotiṣa calendar was based on mean motion parameters. Then evolved the various equations of centre of the Sun and Moon in the Siddhantic period. All these developments from vedic times upto the present will be discussed here.

2. Lunisolar astronomical observations

For study of Sun and Moon, the following types of observations were performed :

1. Study of relative motions of Moon and Sun (The synodic observations).

2. Study of Moon's motion among the Stars (The sidereal lunar observations).

3. Study of Sun's motion among the stars (Sidereal solar observations). Due to glare of Sun, most of the solar observations were done at the rising & setting using analytical approaches based on Lagna and Saptama Lagna.

4. Study of Sun's north - south course throughout the year and daily diurnal motion. Similar observations for Moon. (Also of planets later).

Through the studies of phases of moon, the synodic period of the same was determined. The observations started from the conjunction of Moon with the Sun (i.e from the ending moment of Amāvāsyā). The magnitude of this month is about 29½ mean solar days. Whenever Moon is heliocentrically visible after sunset, one kalā tithi is said to be completed. During first half of synodic month of the Moon 15 kalā tithis are completed by the ending moment of Pūrnimā. Note that earlier, there were no degrees to represent the longitudinal differences between the Moon and the Sun. Only rough Kalā tithi was used. The tithi so defined was the forerunner of the present day tithi which is defined in terms of elongations of the Moon. Sidereal period of the Moon (i.e. the time period of Moon from a star (usually Aswini yogatārā) to the same star after completion of one full cycle was determined through naked eye observations. This period is about 27⅓ mean solar days. These observations made ancient sages acquainted with the nakṣatras or the asterisms of the lunar zodiac. The list of 27 nakṣatras was complete in remote antiquity although it appeared late in Taittiriya Samhitā.

It may be pointed out that the names of the days were given against the names of nakṣatras in Rgvedic tradition as is evident from Rgvedic verse:-

"Aghāsu Hanyante gāvaḥ Arjunyoḥ paryuhyate"

i.e. At the time of Sūrya's marriage, the cows (in the form of dowry) were taken to the bridegroom's home on Maghā day and they reached the destination on Phālguni day. Clearly the names of days were those of nakṣatra. Such a tradition cannot start unless the complete list of 27 nakṣatras was known, as one nakṣatra is to be used for per-day nomenclature. Here it is to be mentioned that in prevedānga jyotiṣa tradition, there were only 24 nakṣatras. The three double nakṣatras Phālguni, Aṣāḍhi and Bhadrapadā were not divided into pūrva and uttarā each (1989). Then the total numbering was 24. In order to connect the nakṣatras (one per day) with the daily motion of the Moon 27 or 28 were needed, as the synodic month consists of 27⅓ mean solar days. In this attempt 27 and 28 divisions of the zodiac came into vogue at different stages of the spring equinox. These facts are clear from the oral Sruti records preserved in Sūrya-prajñpti and other post-vedic purāṇic and other literatures. The nakṣatras were categorized on the basis of time, the moon takes to traverse the intercepts between consecutive yogatārās. This unequal division of nakṣatras, an old pre-vedanga tradition, was replaced by Ṛsi Lagadha with equal division system of nakṣatras.

The period of the Sun was determined using the daily observations of the rising of the same throughout the year, from winter solstice to summer solstice and back. Here we have used the word "period of the Sun", in order not to distinguish between the tropical and sidereal periods at that stage of primitive observations. The observations of rising and setting of Sun were done at the horizons. It is evident that the year length so measured, was tropical in nature but it was taken to be sidereal (Because of no distinction between tropical and sidereal years at that time). The experimental errors overmasked the numerical difference of magnitudes of the two. Thus in those olden times, although the year length was intended to be just the period of Sun, but experimentally it happened to be tropical. In reality they intended the year to be seasonal, but tried to connect the same taking a star as beginning point of zodiac. The experiment described here is reported in Kātīya Sulba Sutra and Sūryaprajñapti (around 3rd. century B.C.) and later by Bhaskaracharya and others.

3. Instruments used during presiddhanta period

In all these developments during prevedic and vedāṅga periods, simple instruments were used. Kātyāyana Súlba - Sūtra, Purāṇas and Prakrita texts like Sūrya-Càndra prajñaptis, Jyotiṣkaraṇḍaka, in Buddhist Pāli literature, have preserved the earlier Sŕuti traditional records. The Sārdūlakarṇāvadān of Buddhist tradition too has interesting records of pre-Siddhānta observational astronomy. In all these works the following instruments are found to be used in observations of sun, moon & planets.

Simple Arc chord geometry on a plane ground: A simple stick or nalika was used for observations of Sun, Moon, Planets and even stars at the time of their acronycal diurnal rising and setting. Kātyāyana Sulb Sūtra and prakrit texts have detailed records of these observations. For estimating latitudinal or declinational north south shifts with respect to eastern horizon, a davarikā (thread) was used to construct the chords. These observations were used to determine -

(1) Solar year (2) Latitude of the moon (3) Estimating orders of planatary latitudes.

The Gnomon: Earlier records of developments show the use of Paurusi Cĥāyā (man's shadow) as found in prakrita texts like Sūrya prajñapti and also in Buddhist texts like Sàrdulakarnāvadāna. The latter uses a gnomon with length = 7 angulas (or 7 units in general) Theoretical texts adopted 12 angula Sȧnku (the gnomon).

This instrument was used : (1) In determining day time lapsed or remaining at any instant. (2) To determine the seasons on the basis of variations of midday shadow lengths over all the months of the Solar year. Prakrita texts and Sārdūlakarṇāvadāna have beautiful records of such observational reports. In the attempts star clocks came into being. (3) Gnomon was used to standardize the units of time on the basis of shadow lengths during equinoxial days. Even during night, sometimes Moon's observations were done using gnomonic shadows, under the light of the latter. Atharva-vedānga jyotiṣa has records of gnomon studies during day and night.

Clepsydra (The water clock): This instrument was used to know the time during the day and night and was standardized using gnomon shadow observations simultaneously (Sharma, 1979).

4. The tedious problem in early observations

The most confusing problems in observations of remote antiquity were caused due to intermingling of rotational velocity of the Earth with the proper motions of the Sun and Moon. Weeding out the rotational velocity of the earth from the proper motion of these celestial bodies under diurnal motion, was a very tedious task for the early seers. Spiral like motions of Sun and Moon towards north and south under daily diurnal movements was referred to as Maṇḍala-gati (Sharma, 1985). There were some paradoxial confusions as follow :-

a) Variation of speed in diurnal motions :

Sun, Moon and Stars under diurnal motion have maximum velocity at the time of rising at the horizon. Their velocity decreases as they move towards zenith. They appear standstill at the time of transitting the meridian and is maximum at setting. In case of Sun, this type of behaviour is represented by the shadow of the gnomon. The velocity of shadow is maximum at Sun rise, it starts decreasing as the Sun moves towards the zenith. It is standstill as the Sun transits the meridian near the zenith. The velocity starts increasing again as the Sun moves in the western hemisphere and becomes maximum again when the Sun is setting in the western horizon.

b) Moon higher than the Sun :

In the spiral like motion in the north south ward courses of journey (due to every day shift of diurnal Maṇḍala in Uttarāyaṇa and dakṣiṇāyana motions) Moon goes beyond the Sun in the extreme position towards the north and south. This has given rise to paradoxial confusion that Moon is above the Sun in the vertical direction. In fact it is the extreme north south angular height of the Moon beyond the Sun due to 5° latitude of the former.

c) Moon slower than the Sun :

This again is a paradoxial confusion because in this context it the resultant velocity of the Moon with respect to the rotating Earth which is evidently about 12° per day towards east with respect to the Sun. On new Moon day, both set in the western horizon simultaneously. On the day of crescent of the Moon, the Sun sets first and the Moon later. Evidently the resulting velocity of the Moon is less than that of the Sun. In the same way the Sun would be moving slower than the stars. Ancients had to weed out the rotational velocity of the earth very carefully in order to resolve the paradox and get the inference that Moon travels about 13 times faster than the Sun (Sharma, 1993).

d) Determination of astronomical parameters

Other equipments used along with these instruments were tanks and balances for collecting and weighing water amounts equivalent of parametric time units. The water in units of palas equivalent of nālikā (Nādikā) or ghati was stranderedized through simultaneous use of gnomon and clepsydra. The units equivalent to parametric values were collected and measured. In the analysis, they had to be very careful about the fact that Maṇḍala-gatis (diurnal motions) were mixed up with the rotation of the earth and these were to be separated out very tactically (Sharma, 1989). Such attempts paved the basis of determination of Luni-Solar parameters which were later used in V.J. and Siddhantas.

5. Pañcānga elements in vedic vedāṇga Jyotiṣa and period

Pañcānga as it stands today has five elements : (i) Tithi (ii) Vāra (iii) Nakṣatra (iv) Yoga (v) Karaṇa

In early vedic tradition, tithi was just the rough kalā (Phase) tithi based on observation of phases of Moon Aitareya Brāhmaṇa has another definition according to which, tithi is just a lunar Sāvana day and night. As solar Sāvana day is from sunrise to sunrise at east horizon the next day, the lunar day (Tithi) too was defined on similar grounds as the duration between Moon rise to Moon rise at horizon the next day. Actually time interval between Moon rise to Moon set is the lunar light day and the time between Moon set to Moon rise is the lunar night. Karnas as half Tithis originated in this tradition. Athārvavedanga Jyotiṣa shows that Moon rise to Moon set is the lunar day - Karṇas and Moon set to Moon rise, the lunar night - Karṇas. Thus there are two Karṇas a day. These are the natural lunar light day & lunar night. But later Siddhāntas defined tithis as successive 12° each elongational - excesses w.r. to Sun, starting from new Moon to full Moon and back to new moon. Thus completing sixty Karṇas in a synodic month. These two separate definitions created confusion between Arab scholars Alkindi and Alberuni as these two different definitions got migrated to Arabs at different times.

Nakṣatra is the position of the Moon among zodiac asterisms. Duration of the Nakṣtara is the time taken by Moon to traverse 13° - 20' zodiac intercepts starting from Aswinī Yogatārā. 27 Nakṣatra complete the full cycle of 360°. The asterisms start from Revati star ξ piscium.

Week days did not exist in vedic and V.J. period, as during those times, days were named against Nakṣatra occupied by Moon on that day. But Baudhāyana Súlbasūtra and Atharva - vedāṅga Jyotiṣa have the weekdays. So the Babylonian origin of week days based on Horesá (Lord of the hour) is still under question mark.

Yoga is another element in Pancāngā, defined as the sum of longitudes of Sun and Moon. Like nakṣatra these have 13° - 20' zodiac span each and 27 of these complete the full cycle of 360°. This mathematical parameter yoga came into being in attempts to predict the phenomena of eclipses. If latitude of Moon is considered to be zero, then the declination of Sun & Moon are equal if

$$\sin(\lambda_s) = \text{Sin}(\lambda_m)$$

where λ_s and λ_m are longitudes of Sun and Moon respectively.

From the above equation we get $\lambda_s = 180 - \lambda_m$

Hence $\lambda_s + \lambda_m = 180°$

This defines one of the yogas mentioned in V.J. In fact V.J. has mentioned two yogas (Bhatt, 1968) corresponding to equality of declination of Sun and Moon towards north and south of the equator.

The earliest calendar might have been having only one element Tithi (Dixit, 1963). Later came Nakṣatra and other elements successively. In V.J. we find only these two elements. In addition to these, only two yogas Vyatīpāta and Vaidhṛti are also mentioned. Basically the V.J.

calendar has only two elements.

In V.J. calendar there is the 5 year yuga system as per parameters of luni solar months, there are 2 intercalaries during 5 year yuga (Dixit, 1963). In fact the intercalaries of V.J. are in excess and one has to drop some of them in order to keep the V.J. calendar in tune with the seasons.

6. Siddhānta - period (The period of theoretical astronomy)

The pre - siddhānta astronomy gave the synodic and sidereal months. More instruments with better accuracy, came into being during Siddhānta period. The inequalities of Sun and Moon were to be improved through observations. In Pancasiddhāntikā of Varahamihira, (Pingree 1983; Sarma 1993) the equations of centre of Sun and the Moon are given in the form of additives or subtractives varying with the time and in some formulae even sine functions are used. Aryabhata (499 A.D.) gave the sine table for these but there is no doubt that even earlier than Aryabhata the sinusoidal forms were existing with mean anomalies as the arguments.

Earlier texts like Sūrya Siddhānta etc. use only one equation of centre of Sun and Moon called Mandaphala (मन्दफल). In fact the Indian lunar and solar inequalities are based on actual observations and analysis of two special eclipses which give $5° - 1$ equation of centre of Moon and $2° - 10$ equations of centre for the Sun. The two eclipses (lunar in general) confirmed to the following situation (Sharma, 1979) :- (i) One eclipse when the Sun was at its apogee and Moon 90° away from its own apogee (approximately) (i.e. 1st equation of centre of Sun was zero and 1st equation of centre of Moon was maximum). (ii) In the second eclipse, the Sun was 90° away from its apogee and Moon at its own apogee. i.e. the 1st equation of centre of Sun was maximum and that of the Moon was zero.

Before we go ahead with more discussions of this point, it is important to point out that 1st equation of centre is consequence of switch over from circular orbit to ecliptical one. This is the first most important term of the Kepler equation. The universal law of gravitation, yields many more inequalities for the Earth-Moon-Sun system. (Sun being the 3rd body perturbing the two body Earth-Moon system). The perturbation function in celestial mechanics treatments is expanded in terms of Lagendre Polynomials and in turn in terms of many sine and cosine functions and secular terms. In the perturbation theory of 3 body Earth-Moon-Sun system the most important terms are :-

1. Evection $= 1° - 15'$ Sin $(2T - \alpha_m)$
   where T = Tithi = Longitude of Moon − Longitude of the Sun.
   α_m = mean anomaly of the Moon (w.r. to apogee).
2. Variation (having fortnight period)
   $= 34'$ Sin $(2T)$
3. Annual variation $= 10'$ Sin (α_s)
   Where α_s = mean anomaly of the Sun.

The first equation of centre from Kepler's equation yields -

$376' \text{Sin}(\alpha_m)$

Now let us come to the discussion of 1st. equation of centre in Sūrya Siddhānta (S.S.) Since the deviation due to evection at T = 180° yields.

$$376' \text{ Sin}(\alpha_m) - 1° \ 15' \text{ Sin}(\alpha_m) = 376 \text{ Sin}(\alpha_m) - 75 \text{ Sin}(\alpha_m) = 5° - 1' \text{ Sin}(\alpha_m)$$

hence $5° \ 1' \text{Sin}(\alpha_m)$ is the equation of centre of Moon. Thus it is clear that if the Sun at 90° away from its own apogee then the equation of centre of Moon has amplitude = 5° 1′.

Sun's equation of centre has argument α_s. Actual modern value of 1st equation of centre is given by

$1° - 55' \text{ Sin}(\alpha_s)$.

When the Sun is at apogee it is 1° 55' but at the same time the annual variation of the Moon is –10'. While computing the tithi for the eclipse calculations, the first equation of centre of Sun and the annual variation for the Moon get subtracted. This yields Sun's Mandaphala plus annual variation = 2° 6′ (Ketkar, 1898). The difference is due to nonrealisation of exact ideal conditions. Thus 2° – 10' is the 1st equation of the Sun in most of the Siddhanta texts. This analysis explains the Saidhāntika values of amplitudes of 1st equation of centre for Sun and Moon as used in most of the Siddhānta texts.

7. Perturbation corrections of Moon in Siddhāntas

We have already explained the 1st equations of centre for Sun and Moon as used in Sūrya Siddhānta and in most of the later texts. These traditional equations for centre, result due to hybridization of some higher perturbation terms. Lunar 1st equation of centre is hybird of actual Keplerian equation of centre and the most important gravitational perturbative inequality the "Evection". Solar equation of centre includes the Moon's annual variation with sign changed. These could result into reasonable good success in predicting eclipses as at T = 0 or 180° (Amā and Purnimā) the evection hybridizes with 1st equation of centre and at the same time the fortnightly variation is zero and the 4th. perturbative inequality is also balanced by the hybridized annual variation, summed up in the Sun. It can be mathematically shown that there will be cases where eclipse predictions too may be wrong but rarely. The duration of the eclipse, beginning and ending may be sometimes more erroneous than the middle of the eclipse. Sometimes eclipse may be missed or even may be predicted without possibility of occurrence but in rare cases.

On the contrary, the other events like occupations of stars etc. are likely to be predicted wrongly (on tithis other than syzygies Amā and Pūrnimā). Thus improvements in the equations of centre or introducing more corrections with different arguments were most necessary.

In spite of all hurdles, in predictions of other events, Acharyas did not accept any Lunar inequality blindly without checking its proof validity. Bhaskracharya says "अत्र गणित - स्कन्धे उपपत्तिमानेवागम : प्रमाणम् " i.e. in the field of mathematics, only those verbal testimonies are to be taken as valid which are mathematically proved. In fact accepting any correction without proof could worsen even the possible predictions on the basis of existing theory. For example if someone insists that Moon of S.S. must be corrected for annual variation, then accepting this advice and implementing the same would have rendered all eclipse predictions a complete failure. One would have to know that this is extra subtractive from Sun's equation of centre and would have to be taken out of the same, while applying this correction in case of Moon. Due to such reasons Acharyas never accepted any verbal testimonial type lunar corrections from any foreign sources. Note that even Almagest was never used by Indians before Jai Singh Sawai when Jagannath Samrat translated the same in Sanskrit in early decades of 18th. century A.D. or so. Before these, there were very important efforts to correct the position of Moon. Munjal (10th A.D.) tried to correct for deficit of evection. Shripati (11th.) Bhaskara (12th. A.D.) Ganeśa Daivajña (16th A.D.) talks of error in longitude of Moon. Chandra Shekar Samant (19th A.D.) tried to improve the parameters. Even at the time of Jai Singh independent observations were performed to correct the position of the Moon. All these attempts were independent without any bias from the west. This clarifies the fact that the Indians did not at all accept from west and nothing like $2° - 10'$ equation of centre of Sun occurred in the wester tradition. David Pingree's arguments and of others following him, without any analysis, do not stand the mathematical checkups. In Indian tradition equations of centre of Moon developed gradually independently. The list of all these in chronological order and similar developments in the west are summerised below.

Inequalities of Sun and Moon in Indian Astronomy

a) Mean longitudinal motions studied in vedānga Jyotiṣa traditions.

b) Latitude & declinational motions studied late in Jain and Puranic traditions.

c) Additive, subtractive corrections in the beginning of Siddhāntas . In early Siddhantas in Pañcasiddhantikā .

d) Sinusoidal corrections :
Sun's only 1st equation of centre $\epsilon_s = -2° - 10' \mathrm{Sin}\,(\alpha_s)$
where $\alpha_s = \lambda_s - \lambda_{sp}$ = Sun's Mandakendra (Anomaly).
where λ_s = Longitude of Sun, λ_{sp} = Longitude of Perigee of Sun.

The modern value of the amplitude is $1° - 55'$. Note that the value in Sūryasiddhānta includes Moon's annual variation with sign changed.

(e) Equations of centre of Moon :-

(1) First correction $\epsilon_{m1} = -5° \mathrm{Sin}\,(\alpha_m)$ Siddhāntas,
where $\alpha_m = \lambda_m - \lambda_{mp}$, λ_m = Longitude of Moon.
and λ_{mp} = Longitude of Perigee of Moon.

(2) 2nd correction $\epsilon_{m2} = -144' \text{ Sin (T) Cos } (\lambda_s - \lambda_{mp})$
(Munjāl 932 A.D.). (Sripati (1028 A.D.) modified it a little).
(Hybrid of evection and remainder of 1st.).
here $T = \lambda_m - \lambda_s$ = Tithi

(3) 3rd. correction (Variation) $\epsilon_{m3} = 34' \text{ Sin } (2T)$.
Some claim the credit of Abulwafa (975 A.D.). In fact Abulwafa happened to find a remainder term of Ptolemy's equations of centre but not the variation.
(Bhāskara (1150 A.D.) found it through his own observations of Moon in gola yantra much before Tycho - Brahi (1546 - 1601 A.D.).

(4) 4th. correction (Annual variation).
$\epsilon_{m4} = 10' - 27'' \text{ Sin } (\lambda_{sp})$
Independently found by Chandra - Shekar Samant in 19th. century.

(5) Reduction to ecliptic by Aćuta of Kerala (1550 - 1625 A.D.). Nityānanda (1639 A.D.)
According to modern astronomy the sum of 1st. four equations of centre of Moon are (taking Anomaly w.r. to Perigee) :-

$$C = -377' \text{ Sin } (\lambda_{mp}) - 76' \text{ Sin } (2T - \lambda_{mp}) + 40' \text{ Sin } (2T) + 11' - 10'' \text{ Sin } (\lambda_{sp}).$$

$$= -301' \text{ Sin } (\lambda_{mp}) - 152' \text{ Sin (T) Cos } (\lambda_{mp}) + 40' \text{ Sin } (2T) + 10' - 27'' \text{ Sin } (\lambda_{sp}).$$

8. Ayanānśa Controversies

As already discussed, the Hindu calendar from remote antiquity, was intended to be tropical (sāyana) in order to have consonance with seasons. But due to no distinction between tropical & sidereal solar years, the zero of zodiac was connected with star Aswinī yogatārā. Although in vedic and vedānga periods, the zero of zodiac shifted to loose consonance with seasons but it was Lalla who first mentioned 6° angle of precession. (Ayanānsa) and tried to accommodate it in solar ingresses (Sankrāntis). Alberuni has pointed out confusion in Sankrāntis throughout Indian territories. From vedic times upto Brahamasphuṭa Siddhānta of Brahmagupta. Even later the pañcāngas though with sidereal features, were thought to be tropical, supposedly to be in consonance with seasons).

Ayanānśa got adopted in the tradition after Lalla. Pañcanga were kept intact in sidereal form with the hope that the spring equinox will oscillate between –27° to +27° around, which is against the law of gravitation. Since the sidereal year of Sūrya Siddhānta is in error by 8½ palas, the link with this zero of zodiac got lost with time. As per Sūrya Siddhānta Ayānānśa, the zero was at ξ piscium. In fact there were some attempts to correct the Ayanānśa and in this process, different astronomers fixed zero of zodiac at different sidereal points.

In the 19th century A.D., many Pañcanga makers started accommodating many more inequalities in the position of the Sun and Moon as revealed through perturbation theory based on law of gravitation. During this process of improvements the zero of zodiac became a vexed problem because, on account of shift of zero from ξ piscium, due to wrong Ayanānśa velocity, the zero had to be brought ahead by about 3° to 4° which was not possible without disturbing all the festivity dates. G.S. Apte, C. Shastri and many others were involved in mutual controversies for many decades. On the advice of B. Dixit, V. B. Ketakar (1898) adopted cítrāpakṣa in which zero was fixed 180° away (i.e. in a position with the 1st mag. bright star Spica). This point is the same as the one in 1800 shaka according to Ayanānśa of Sūrya Siddhānta. This is called Citra pakṣa. Calendar reform committee under the chairmanship of M.N. Saha fixed the Ayanānśa 23° – 15' on 1st Jan. 1955 and suggested the use of the correct Ayana-velocity for future. For planetary positions constant precession 23° – 15' is used. This school is called Sthirāyanānśa pakṣa. For nakṣartas , this school too adopts variable Ayanānśa of Citra pakṣa. The school advocated by G.S. Apte and Lokamanya Tilak is referred to as the Raivata pakṣa . According to this school ξ piscium is the zero of the zodiac. The Citrā pakṣa got adopted by most of the Pañcanga makers who corrected the Moon's & Sun's position on the basis of gravitational perturbations. This system is usually referred to as "Dṛk-pakṣa". In fact the problem of Ayanānśa could never be solved, but considering the zero of a circle to be the arbitrary, the Citrapakṣa was agreed upon. These days (in 1995), the Citrapakṣa Ayanānśa is 23° – 47'. There are other schools too which have very few followers.

9. Solar adjustments and nomenclature of lunar months

In order to keep the lunar months, in consonance with seasons intercalaries are to be inserted. But there must be a systematic plan for the same, so that adhoc insertion may be avoided. For this purpose, the lunar months are tagged on to the solar ingresses (Sankrāntis). There are two systems of naming lunar months : (a) Súklādi system and (b) Kṛṣnādi System

In the first case the months start from new moon while in the second case, the months start with the beginning of Kṛṣṇa pakṣa just after purnima. In south, Súklādi system is prevalent while in north the later one is in use. In the two systems the name of the Súkla pakṣa is the same while the names of Kṛṣṇa pakṣas differ. The names of Kṛṣṇa pakṣas of first system leg behind by one to those of the Kṛṣṇa pakṣas. For example Jyeṣṭha Kṛṣṇa of Súklādi system is the same as the Āṣaḍha kṛṣṇa of the Kṛṣṇādi system. In fact, theoretically the Súklādi system of nomenclature is justified. In case of intercalary month, in both the systems the Kṛṣṇa pakṣas of both are the same. Theoretically nomenclature of the intercalary is according to Súkladi system in both the systems.

Name of Súklādi month is determined from the position of the Sun at the ending moment of Amāvāsyā of the same. i.e. from Sun's position at the ending moment of the month (i.e. at end of Amā). The Súklādi lunar month, ending with the sun in Meṣa is called cāitra. The one ending with Sun in Vṛṣa, is called Vaisākha and so on. In Kṛṣṇādi system, the name of Kṛṣṇa pakṣa is to be advanced by one. This definition avoids any adhoc insertions and intercalates on extra month at the proper place in the calendar automatically. In the intercalary month the religious vratas and parvas are prohibited.

As discussed above, the two śuklādi months having amāvāsyās ending with Sun in the same zodiac sign, constitute an intercalary and an ordinary month both with the same name. In other words a lunar month without Sankranti (i.e. the first one of the two) is intercalary. This definition introduces intercalaries in a fool proof way.

There are occasions when there can be two sankrāntis in a lunar month. In this case, one month appears missing - This is referred to as kṣaya or decayed lunar month. The nomenclature criterion based on sankrāntis, adjusts the Kṣaya months automatically in a systematic way but there arise problems in the festivities celebrations which we will discuss in the next section. Note that whenever Kṣaya month occurs, there are two lunar months without sankrānti before and after the Kṣaya month. The month without sankrānti before Kṣayamasa, is called Sansarpa. It is not like an ordinary intercalary while the second month devoid of sankrānti, after Kṣayamāsa, is the real adhimāsa (intercalary).

10. Vrata - parva - dates in the Pañcangas

The dates of Vratas and Parvas etc. are indispensable parts of Pañcangas. The main criteria for religious festivities are based on Tithis but there are problems in deciding the dates of religious vratas and parvas because of nonconsonance of lunar and solar days. In different parts of the country, earlier (or even now) different siddhānta texts were in use. Sūrya Siddhānta was used in north, Brahmasphnṭa Siddhānta etc. (Caṅḍū pakṣa) in Madhya pradesha etc and Āryabhaṭa Siddhañta based vākya paddhati in south for preparation of Pañcangas, which differ somewhat in solar ingresses and other calculations. Also the different Dharma-Śástra texts like Dharma Sindhu Nirṇaya-Sindhu and Jai Singh Kalpadruma etc. are being used for deciding the vrata parva dates in different parts of the Nation. The Nibandha Karas of Dharma- Sástra try to have the same decision criteria for the festivals vrata and parvas, but due to lack of adoption of the same standard meridian for all Pañcangas and due to differences in Siddhānta text in use, and many times due to different opinions of Dharma-Sástra texts and also because of difference in customs in different parts of the country, there are confusions causing non-uniformity in the celebrations (Sharma, 1982).

It may be remarked that Hindu calendar is most scientific (Sharma, 1983) in the sense that it always makes uses of true position of Sun, Moon and sometimes that of Jupiter etc (for deciding Kumbha parvas and some special yogas), while other calendars of the world make use of mean elements based results for astronomical phenomenon. The main cause of confusion in Hindu festivals is this very trend of sticking to the true positions.

As an example of the scientific background for observances of vratas parvas (Jani 1983), consider the time of Sun's entry into a zodiac rashi which is considered as auspicious time "Puṇya kāla". It starts when the Sun's eastern limb enters the periphery of rāsi and its middle is when Sun's centre enters the rasi and the duration of Puṇya kāla finishes at the moment when the Sun's western limb crosses the beginning edge of the rasi. It is interesting to know that for Karka and Makara Sankrāntis, the duration of Puṇya kāla is more because of the stand still position of Sun at solstices. These duration indicate the precision with which the ancients could determine the true instant of these solar ingresses. The calculated Puṇya kālas are reported in the Pañcangas. Such observances might have given much incentives for improvements in theories.

Although Hindu calendar has confusions mainly due to efforts to adopt most scientific luni solar position based calculations. The confusions are not only in our religion. Islam has many more frequent confusions. According to William Hastings, in Christianity too sometimes there are differences in all the 63 lunisolar religious festivals starting with Good Friday or Easter Sunday. All these festivals sometimes differ by 5 weeks or even more throughout the year in different Churches throughout the world. These confusions are caused by the nonuniform criteria adopted by two schools in Nicea meeting in Rome in 3rd century A.D. The differences could not be resolved. Only solar festival Christmas day is celebrated on the same day by Christians all over the world, all other parvas differ by 5 weeks. In the Hindu calendar there may be confusions due to the non-uniformities in criteria etc. in different parts of the country but all try to adopt true position of Sun and Moon and accommodate the most advanced Lunar theory in preparation of the Pañcangas.

11. Controversies over festivals

Most of the objections against the adoptability of modern school which makes use of all prominent inequalities in the Moon and Sun are based on the maximum and minimum duration of tithis. It may be pointed out that the maximum and minimum of tithis according to Sūrya Siddhānta (S.S) are 65 ghatis and 54 ghatis respectively. For all tithis irrespective of their numbers or the bright dark halves, they belong to. It is due to the fact that S.S uses only the first hybrid equations of centre in the celestial longitudes of Sun and Moon. On the other hand according to the modern school (Dṛk pakṣa School as it is called) the situation is different. This school believes in the observational validity of Lunar and Solar theoretical corrections. The maxima and minima of tithis according to Dṛk pakṣa depend upon the numbers of the tithis. The calculations of the maxima and minima of tithis are done equating the time derivative of tithi to zero (Sharma, 1979).

$$\frac{dT}{dt} = 0$$

where $T = \lambda_m - \lambda_s$.

Here the longitudes include Mandaphala, evection fortnightly variation and annual variation.

The results are found to depend on number of the tithi. The solutions of the above transcendental equations are listed in Table 1. From this Table we note that :

(1) Maximum of all minima of tithis is around 53.81g and occurs near Krisṅa paksa or sukla paksa Astami (K8 or S8) only.

(2) Minimum of all the minima of tithis is ≈ 50.06g and occurs only near syzygies Amāvāsyā and Pūrṇimā (K30 and S15).

(3) Maximum of all the maxima of tithis is 67.07g and occurs near Syzygies only (K30 or S15).

(4) Minimum of all the maxima of tithis is around 66.85g and occurs near Aṣṭamīs only.

(5) It is clear that the variation in maxima are very small, while the variations in the minima are quite large (54g to 50g).

(6) Because perigee of Moon has velocity ≈ 1° - 40 per month, if any tithi undergoes minimum (maximum) (approx), that very tithi will again pass through maximum (minimum) after about 9 1/2 years i.e. after 4 years 9 months tithi numbered the same but in different fortnight (Kṛṣṇa to Súkla or vice versa) will pass through the same extremum.

(7) If Lunar perigee is near Apogee of the Sun (around 18th Saura Nirayaṇa Āsaḍha only) then tithi can be minimum because of annual variation perturbation.

(8) Since the lunar perigee can be near Sun's apogee, only after 19 years or so, hence minimum of all minima can occur only for some few cycles of Moon after 19 years or so and that too in case of Syzygies during the Saur Asadha month only as the velocity of Solar perigee is almost negligible.

(9) If a given tithi nth. (say) is near minimum at a certain point of ecliptic position of Moon, then after about 8 months (n + 1) th. tithi will undergo minimum at that point.

Pundits following S.S tithi, raise objections against Dṛk school which has minimum tithi = 50g. and maximum = 67g.

Table 1. 1 ghaṭī = 24 minutes = 1 g.

Tithi No.	Minimum (ghaṭīs)	Maximum (ghaṭīs)
0 (or 30) Amā	50.06	67.07
1	56.21	67.07
2	50.65	67.05
3	51.31	66.99
4	52.09	66.94
5	52.85	66.90
6	53.48	66.87
7	53.81	66.81
8	53.81	66.85
9	53.48	66.85
10	52.85	66.90
11	52.09	66.94
12	51.31	66.99
13	50.65	67.05
14	50.21	67.07
15 Pūrṇimā	50.06	67.07

Besides this, there are controversies regarding Kumbha fairs which depend upon the position of Jupiter. The longitude of Jupiter is to be corrected for gravitational perturbation due to Saturn etc.

Also there were Kṣaya month controversies in the years 1963 and 1982 (see Sharma, 1982). The occurrence of decayed month in 1963 took place after 141 years. The decayed months provoked controversies based on switch over to the Dṛk school and also there were different schools which followed different criteria for adjustment of vratas and parvas belonging to the decayed months. One school treated two months in one (Yugala māsa system), the other school treated the first non sankranti month as normal for monthly religious observances and is called Sansarpa. The names of months from Sansarpa to Kṣayamāsa, are changed to have the normal sequence. No month name was missing, only the month with two sankrantis was designated the Kṣayamāsa which was treated normal for monthly religious festivals but inauspicious for mahuratas. The second non-sankranti māsa was treated as the real adhimāsa. This school is called Sansarpa pakṣa. There is a third school which treated the first non-sankranti month to be real adhimāsa and second one as normal month. This school is called Raghunandan school of Bangal. The Yugala māsa school is unacceptable as it creates disorders and disappearance of vratas parvas or even ending of a parva may fall earlier than the beginning. The Raghunandan school too does not stand stringent theoretical checks. Briefly we can say that if kṣāya māsa would have not occurred (As per mean motion parameter) the first nonsankranti month would not have come into being so it is pseudo adhimasa sansarpa or normal for monthly festivities.

12. Conclusion

As a result of efforts of Modern Dṛk School, followers of most of Pañcangas use :

1. Correct sidereal year of the Sun.

2 Corrections to the longitude of the Moon as evidenced from the perturbation theory based on Law of gravitation.

3. Even gravitational perturbations on Jupiter due to Saturn are to be applied for deciding Kumbha fairs.

4. The Cítrā pakṣīya Ayanānśa is acceptable.

5. The most correct velocity of precession of equinoxes is accepted along with nutation correction.

6. In calculating tithis karaṇas nakṣatras and yogas interpolation upto 2nd order are used.

Now even in India, only about 70 % pañcángas are in line with this most evolved Hindu religious calendar. But S.S. is still in use in many countries Nepal, Ceylon, Burma, Jawa, Sumatra, Thailand etc. The Dṛk School is still far away to be practiced there.

Any way we can definitely say that Dṛk School Pañcángas are so evolved as to embrace the most advanced Lunar and Solar dynamical theories. This true luni solar position based calendar is the most advanced scientific calendar of the world. Only at the offset of Kṣaya month, if double month is assumed, it is rendered unscientific and absurd. In order to keep its high scientific order the Sansarpa school is to be followed.

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