Understanding of Periodic Motions and Utilization of this Knowledge in Ancient India

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Abstract

This paper deals with the knowledge of ancient Indians about the subtle periodic motions observable in the sky. This research also answers an important unanswered question in the Indian History - Why 57 BC is the starting year for the Vikram Samvat (Era)? The answer to this is provided from the knowledge of the shifting of the vernal equinox due to the precession of the Earth's axis, various signs of the zodiac, and the historical records of India.

Keywords:

1 Introduction

In India, there are two commonly used calendars: the first one is the Saka which starts from 78 AD when the Shalivahana king of South India defeated the Saka king of Malwa and the second one is called the Vikram calendar which starts from 57 BC. However, it is not known as to why it is started from 57 BC because the king Vikramaditya has been widely accepted as Chandragupta II of the Gupta dynasty, who lived between 375 AD to 415 AD[1,2]. The time span separating the king's rule and 57 BC could not be explained by the historians.

The objective of this work is to find the answer to this question.

2 Calendar Years in India and their Basis

Indians followed lunar calendar where the year was divided into 27 or 28 parts, and each of these are called Nakshatras (asterisms)[3]. There were further sub-divisions within the span of a Nakshatra. The division of the year into 12 months based on various zodiac signs came into practice later on. The names of the twelve months based on these signs and Nakshatras were arrived at due to the position of the sun in a particular zodiac sign[4]. If the sun was in the same sign after the end of the lunar month then, that particular lunar month had an additional month called Adhikmaasa with the same name. The names of the months correspond to the particular Nakshatra on the full moon day. For example, if it was the Chitra Nakshatra on the full moon day then, it was called Chaitra month. In this way, there was reconciliation done between the solar and lunar calendars.

Four important events of the earth's motion around the sun were known in India since the ancient times. These events were: vernal and autumnal equinoxes, and winter and summer solstices.

Figure 1 shows the orbit of the earth around the sun where it shows the position and the orientation of the earth's spin axis on June 21[5]. At this time, the North Pole is tilted toward the sun, and there is summer in the northern hemisphere. Similarly, on December 21, it is the South Pole which is tilted toward the sun. The earth's spin axis maintains same orientation with respect to a three dimensional coordinate system defined at the center of the sun (heliocentric). The X and Y axes of this coordinate system lie in the plane of the ecliptic. The center of the earth moves in this plane as it traverses around the sun.

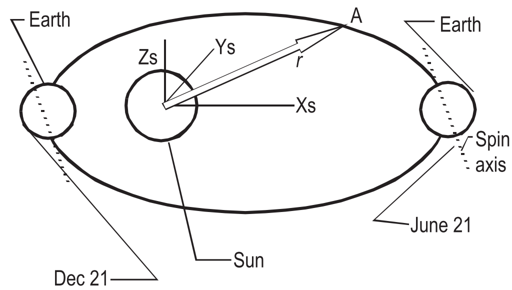

Fig. 1 Earth's orbital motion

The position of the equinoxes is determined at points on the orbit when both poles of the earth are illuminated by the sun's rays. It happens when this axis becomes perpendicular to a line drawn from the origin of the coordinate system to the center of the earth.

Even though the orientation of the earth's axis remains almost the same in a given year yet, its orientation changes over longer time period, i.e., the orientation change is cyclic in nature. One cycle of this change takes approximately 25,800 years. Thus, to notice this subtle change in the sky due to a periodic motion of extremely low frequency, was a very subtle knowledge acquired by the Indian Astronomers since the Vedic times[6]. The earliest description of this precession of the earth's axis of rotation is mentioned by Hipparchus, a Greek living in Egypt in the second century BC[7]. This phenomenon is shown in Fig. 2, and is called the precession of the earth's axis. The precession is caused due to the tidal (differential gravitational) force by the moon, sun, etc., on the equatorial bulge of the earth. This differential gravitational force exerts a torque on the equatorial bulge and tries to get the equatorial bulge aligned with the plane of orbit of the moon if the cause by moon is considered separately. In actuality, it will be the superposition of the effects of various causes. The plane of orbit of the moon is within 5 degrees of the ecliptic and hence the effect of this torque is to get the equatorial plane of the earth coincide with the ecliptic. If the earth were a perfect sphere (without an equatorial bulge), there would be no tidal force and hence no torque exerted by the moon[5,7]. During the precession, the axis generates the surface of a cone whose apex lies on the ecliptic. The rotation, when viewed from the top, is clockwise.

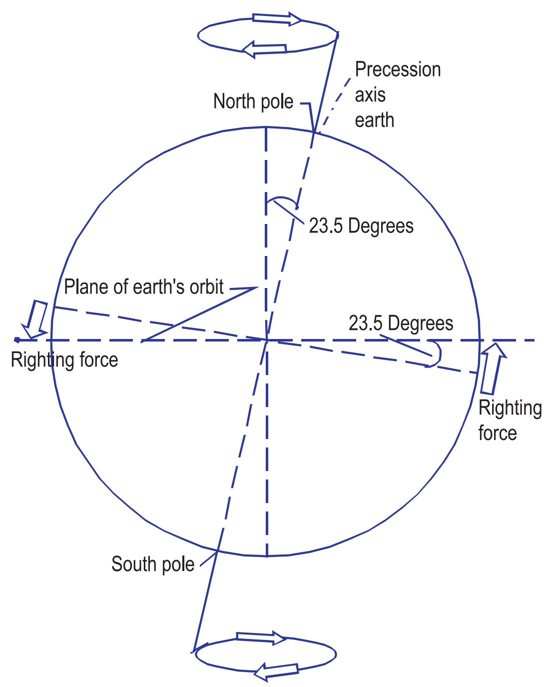

Fig. 2 Precession of the earth's axis

Due to this precession, the lines joining the set of points consisting of two - equinoxes, and solstices, change their orientation on the ecliptic plane as shown in Figs. 3*a*, and 3*b*. It should be noted that the earth's orbit around the sun is almost a circle. The maximum and the minimum distances between the sun and the earth are approximately 152, and 147 million kilometers respectively. Due to the precession, equinoxes take place earlier according to the calendar months. The equinoxes slide eastward on the ecliptic because of precession at the same rate as precession. Sliding through 360° in 25,800 years, every year they (the equinoxes) slide eastward by 50 seconds of arc along the ecliptic. For example, the vernal (spring) equinox which happens on March 21 these days, must be taking place in April in the past. Similar changes take place for the other equinox, and solstices as shown in this figure. Since the season is dependent upon these points, the seasons have also been changing accordingly.

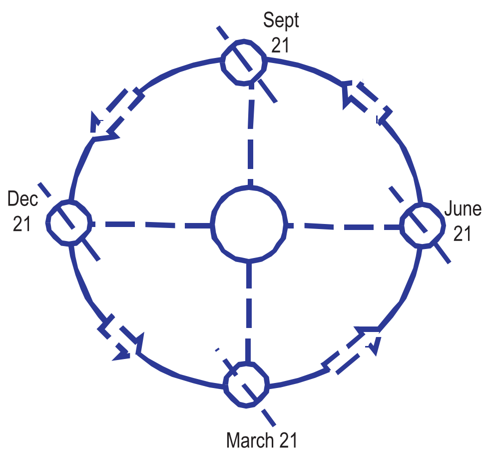

Fig. 3*a* Earth's motion around the sun

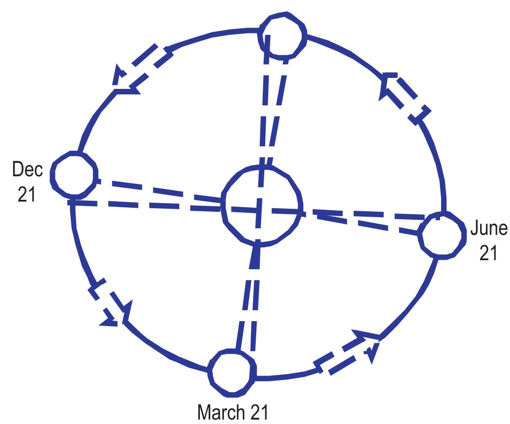

Fig. 3*b* Shifting of equinox due to the precession of the earth's axis

Table 1 shows the months, and seasons in the Hindu system, and it also shows the corresponding names in the Western system.

Table 1 The months, and seasons of the Hindu calendar

	Hindu month	Western months	Name of the Hindu season	Western name of season
1.	Chaitra	March–April	Vasanta	Spring
2.	Vaishakh	April–May	Vasanta	Spring
3.	Jyeshta	May–June	Greeshma	Summer
4.	Aashaadh	June–July	Greeshma	Summer
5.	Shraavan	July–August	Varsha	Monsoon
6.	Bhadrapad	August–September	Varsha	Monsoon
7.	Ashwin	September–October	Sharad	Autumn
8.	Kaartik	October–November	Sharad	Autumn
9.	Margasheersh	November–December	Hemanta	Winter
10.	Paush	December–January	Hemanta	Winter
11.	Maagh	January–February	Shishira	Dewey
12.	Phalgun	February–March	Shishira	Dewey

In the Western system also, people depended upon zodiac signs to measure the passage of time, and the change in seasons. Here, the ecliptic was divided into 12 parts where each part had a range of 30 degrees. Various zodiac signs are shown in Table 2. In the first column, the names of the zodiac signs are written, and below those are the ones used in the Hindu system (shown within a bracket). The second column shows the abbreviations of these signs. The third and the fourth columns show the span of the signs, and those of the Nakshatras, respectively. The fifth column has the names of the corresponding Nakshatras. These two systems have developed independent of each other, and the parts 12 (zodiac symbols) and 27 (Nakshatras) do not have any relationship other than what is mentioned below. The Hindu epics like the Ramayana by sage Valmiki or the Mahabharata by sage Vyasa composed before the birth of Lord Jesus Christ, refer to Nakshatras only.

The starting Nakshatra is Aswini, and corresponding to the beginning of the zodiac sign Aries. When this development of the zodiac signs took place is not known. Aries was the first sign when the Greek Civilization flourished - this is because the equinox took place at the first point of Aries around 2350 BC.

Table 2 Zodic sings and corresponding Nakshatras

Zodiac Sign	Abbrev	Angle, Zodiac Sign	Angle, Nakshatras (Degrees)	Nakshatras (Asterisms)
Aries	Ar	0	13.3333	1. Aswini
(Mesha)			26.6666	2. Bharani
Taurus	Ta	30	40	3. Krittika
(Vrishaba)			53.3333	4. Rohini
Gemini	Ge	60	66.6666	5. Mrigasirsha
(Mithuna)			80	6. Ardra
Cancer	Ca	90	93.3333	7. Punarvasu
(Karkata)			106.666	8. Pushya
Leo	Le	120	120	9. Ashlesha
(Simha)			133.333	10. Magha
			146.666	11. Purva Phalguni
Virgo	Vi	150	160	12. Uttara Phalguni
(Kanya)			173.333	13. Hasta
Libra	Li	180	186.666	14. Chitra
(Tula)			200	15. Swathi
Scorpio	Sc	210	213.333	16. Vishaka
(Vrishchika)			226.666	17. Anuradha
Sagittarius	Sa	240	240	18. Jyeshitha
(Dhanu)			253.333	19. Moola
			266.666	20. Poorvashada
Capricorn	Cp	270	280	21. Uttarashada
(Makara)			293.333	22. Shravana
Aquarius	Aq	300	306.666	23. Dhanishtha
(Kumbha)			320	24. Shathabisha
Pisces	Pi	330	333.333	25. Poorva Bhadrapada
(Meena)			346.666	26. Uttara Bhadrapada
			360	27. Revati

There is one fundamental difference between the two systems, however. The Hindu system is based on the actual position of the set of asterisms on the ecliptic but the Western astrologers did not change the name of the signs even though, due to the precession, the instant of time when the equinoxes take place in a calendar year, changes as time progresses. It takes place at different points on the earth's orbit, as was shown in Figs. 3*a*, and 3*b*. The Western astrology is called - Tropical astrology. It means that Aries would mean the beginning of the Spring season always, whereas in the Nakshatra - Aswini - it would not be true all the time.

The Gupta Period - The Golden Period of the Indian History[1]

In this period, especially during the reign of Chandragupta II, India reached the peak of the classical age. This king of the Gupta dynasty had famous poets like Kalidasa, and many astronomers in his court at Ujjain, a city referred to as the prime meridian in the Indian astronomy. Further discussions regarding the school of mathematics and astronomy in ancient India can be seen in[8]. According to Joseph, in ancient times the school of astronomy was located at Pataliputra (modern Patna) which was the capital of Magadha. This city has had several names in the course of history such as Patali, Pataliputra, Kusumpur, Pushpapur, etc. This school moved to Ujjain when this king was ruling from Ujjain, as his second capital. Later on, because of the disturbed conditions in North India, these astronomers and mathematicians moved to Kerala province in South India [Joseph, 2000].

This king has also been known as the Vikramaditya. Since he ruled between the years 375 to 415 AD, the question arises - Why is 57 BC, the beginning of the era named after him?

To the author, it was quite clear that to the people in his court, it must have been in their knowledge that something had happened in 57 BC otherwise, they would have chosen a point in time during his rule. But what that could be, especially several hundred years before their time?

Since it had to do with a calendar which, in those days, was based on a celestial event, logically one has to look into the field of astronomy. Going through the books on astronomy, the author thought over an event - the transition of the equinox between Aries to Pisces (according to the Nakshatras - this would be from Aswini to Revati). This transition can also be checked using different softwares on Panchangams (a table used by Hindus to show the position of various planets in 12 houses of the zodiac), if the software can calculate that far back. The precession phenomenon was known to the Hindu astronomers in his court. So, they must have named this transition event in time, as the beginning of the Vikram Era (Samvat).

To verify, if indeed this was the case, let us look at the Table 3 which shows the mean positions of Aswini, and Revati in 1000 BC, and 45 AD[9]. Since the span, in degrees, of each of these Nakshatras is 13.333°, the mean of the two values at any instant of time will yield the position of the transition. The mean positions of these two Nakshatras will be offset by half of 13.333 degrees on the either side of the transition point. The result (the average) shown in Table 3 is equal to 358.39 degrees. It is

Table 3 The transition event between Aswini to Revati Nakshatras[9]

Star	Nakshatra (Asterism)	1000 BC (Degrees) (Given)	57 BC, Calculated by interpolation (Degrees)	45 AD (Degrees) (Given)
· Piscium	Revati	339.73	351.34	352.60
∃ Arietis	Aswini	353.83	5.44	6.70
	Average		358.39	

very close to 360 degrees, and so, one can safely conclude that this was the event the astronomers in the Vikramaditya's court, had in mind. This transition, the position of the sun at equinox can also be seen in Fig. 4[10], which is the sky map drawn using the modern planetarium software. One can clearly see in this figure that the sun is located at the equinox between these two Nakshatras (Aswini, and Revati).

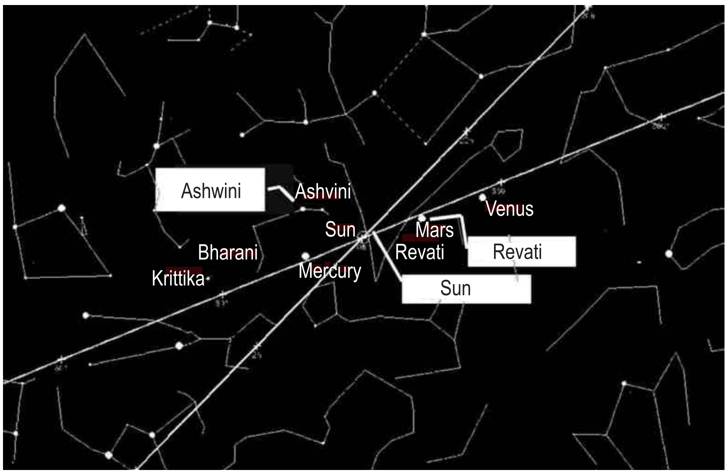

Fig. 4 Locations of the Nakshatras at equinox in 57 BC

Conclusion

In this research work, the history of India was briefly looked into to find the answer to the question - Why does the Vikram Era start from 57 BC? Then, the knowledge of the periodic motions of the astronomies of the Western, and Hindu systems were discussed. Finally, by a calculation, the answer to the question was arrived at. The answer was: It was the transition between the Nakshatras - Aswini to Revati in 57 BC, which corresponds to the transition between signs - Aries to Pisces.

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