Saptarşi's visit to different *Nakşatras*:

Subtle effect of Earth's precession[1]

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Summary

In several ancient Indian texts a mention is made of the movement of the *Saptarşi* constellation (Big Bear or Big Dipper) in the sky, visiting each *Nakşatras* for 100 years. *Saptarşi* is said to visit a *nakşatra* if the *nakşatra* is in the middle of the stars in the first part of *Saptarşi*. Since astronomical objects except planets are more or less stationary in the sky, this is generally considered a fanciful statement devoid of astronomical meaning. We show that this may not be so. We show that the visit of *Saptarşi* to different may be a very significant astronomical observation. The transition is not a constant of time since it depends on the proximity of the *Saptarşi* to the North Pole, which changes due to Earth's precession and relative sizes of different *Nakşatras*. We show that since 8000 BC, *Saptarşi* has visited 5 different *Nakşatras* and for one of them, the transition happening in the span of roughly 100 years. We show that this interpretation allows dating of this belief which is consistent with other evidences of the Harappan civilisation and date different *Saptarşi* Era with calendar dates.

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Introduction

In some of the most ancient texts, a mention is made of the visit of *Saptarşi* Constellation into various *Nakşatras* for 100 years. Filliozat (1962) has comprehensively summarised the literature and we reproduce his analysis below.

The belief in India in a revolution of the Great Bear is mentioned not in treaties on astronomy or even of astrology but in texts giving chronology. It appears under this title in *Bŗhatsaṁhitā* XIII, 3-4 and in several *Purānas* (*Vishnu Purāŋa* IV, 24.105-106 (Gupta, 1922), *Matsya Purāŋa*, 273, 42-44, *Vāyu Purāŋa* 99,421-423, *Bhāgvada Purāŋa*, XII, 2.27-32). *Utpala*, the commentator on the *Bŗhatsaṁhita*, cites about this subject a verse from *Vŗdha Garga* (c.f. Kane, page 520). According to this theory, the seven *ŗşis* (sages) would turn from *nakşatra* to *nakşatra*, remaining 100 years in each of these 27 constellations. Several important events of that era are dated using this concept of *Saptarşi* era. At the time of the reign of Yudhişţhira or of the accession of *Parikşita* or of the death of *Kŗşŋa*, which marks the beginning of *Kaliyuga*, the seven *ŗşis* would have been in *Maghā* (Regulus), in the Leo constellation. One sometimes calculated the centuries, separating 2 reigns by noting from which *nakşatra* to which other one have the 7 *ŗşis* passed during the interval. (For example, *Bhāgvadā Purana*, XII, 2.32, *Vishnu Purana*, IV, 24.112 (see footnote 2), where it is a question of movement from the *Maghā* to *Pūrvaşādhā* (δ and ε stars in Sagittarius), which represents 10 centuries between Parikşit and King Nanda of the Magadha dynasty. Incidentally, this estimate agrees with *Vişnu Purāna*, IV, 23.42, which places the period more precisely between the birth of Parikşit and the royal consecration of Nanda at 1,015 years). Saptarşi's motion is central to many Indian calendars and was used extensively in many parts of Indian subcontinents including Kashmir and Nepal.

This strange conception has always intrigued the historians of Indian astronomy, who have at once suspected that reference of movement of the "Great Bear" must have been related to the precession of the equinoxes (Kaye, 1924, Aiyer, 1901). But one can discover its probable origin and find out the epoch in which it originated.

Filliozat (1962) refers to commentary by *Sriratnagarbha Bhattācārya*, on the *Vişnu Purāna,* called "*Vaişnava – kūţacandrikā",* which interprets the indications in the text, by pointing out exactly when the *Saptarşi* may have been in *Maghā*. He claims that the conjunction in question consists of the coincidence of the big circles passing through the middle of the gap between α and β of the Great Bear, and through a star of one of the *Nakşatras*. This takes for granted, in the particular case of *Maghā* (Regulus in Leo) the positions of the North Pole, as they were around 1,000 BC. He further analyses that the text deals with a region situated at the latitude sufficiently low, so that the Great Bear is not in the circle of perpetual vision, and that it presents an apparent rising. At 1,000 BC, this altitude must have been lower than 15^o. This means, in ancient times, the rising of α and β of the Great Bear was observable only in the regions of peninsular India.

This text, as it is interpreted by the commentary, refers to a real but particular situation. Its error lies in its having generalised into a law, a revolution which does not exist, and whose impossibility has been rightly called in question by the astronomers. This explains that they have left it only to the tradition of chronologists. If the astronomer Varāhamihira does speak of it, it is with reference to chronology.

It is therefore conventionally assumed that the so called visit of *Saptarşi* to different constellations is a false statement and has no relation to astronomy, a deduction made on limited data. However, the *Saptarşi* cycle of 2,700 years has been considered important in the Indian chronology.

Abhyankar and Ballabh (1996) give a completely different interpretation of the entire *Saptarşi* motion by saying *Saptarşi* represent the summer solstice and *nakşatra* is a cryptic reference to an angle of one degree in the sky. They argue that this statement merely gives rate of precession as calculated by *Vridha Garga* in roughly 500 BC. We find no need to pursue this idea as number of ancient texts identifying *Saptarşi* with Ursa Major outnumber these stray as well as ambiguous references by far.

More recently, there have been attempts to explain this concept of *Saptarşi* era employing modern star chart software. These calculations have not been checked for error margins and give false sense of accuracy. Apparently, most commercial software use simplified algorithms and give accurate results only for a period of about 250 years on either side of year 2000 A.D. The calculations involving position of the Sun, the Moon and most other astronomical objects are much more complex and the error margins increase more and more as we go further away from 2000 A.D. We feel the analysis on the subject is not conclusive and we revisit the problem with more vigour.

The Original Reference

As mentioned above, the oldest reference to the *Saptarşi* cycle is in *Vişnu Puraņa*. The relevent *Shloka* from is reproduced here.

सप्तर्षीणां तु यौ पूर्वौ दृश्येते ह्युदितौ दिवि ।
तयोस्तु मध्ये नक्षत्रं दृश्यते यत्समं निशि ।।१०५।।
तेन सप्तर्षयो युक्तास्तिष्ठन्त्यब्दशतं नृणाम् ।
ते तु पारिक्षिते काले मघास्वासन्द्विजोत्तम ।।१०६।।

"Take those two stars of *Saptarşi* (seven sages) which are seen first after the rise. The *nakşatra* which is seen in the middle of it at equal distance at the night, is said to be residence of *Saptarşi* for 100 years of man's life. Oh great *brahmin* they were in *Maghā* (Regulus, Leo) at the time of *Parikşit*." (Vişnu Purana, IV 4.105-106)

Śriratnagarbha Bhattācaryā, in his commentary explains this in more detail. The part here is reproduced from Filliozat (1962).

कलेश्च प्रवृत्तिं वृध्दिं च वक्तुं लक्षणमाह सप्तर्षीणामिति प्रागग्रशकटाकारं तारासप्तकं सप्तर्षिमण्डलं तत्र पूर्वतः ईषाकारे तारात्रयेग्रमध्यमूलेषु मरीचिसभार्यवसिष्ठाङ्गिरसः ततः पश्चिमे खट्वाकारे ताराचतुष्के ऐशानाग्नेयनिर्ऋतिवायव्यकोणेष्वत्रिपुलस्त्यपुलहक्रतवो यथाक्रमं तत्र यौ पूर्वौ प्रथमोदितौ पुलहक्रतुसंज्ञौ तयोस्तत्पूर्वयोश्च मध्ये समं दक्षिणोत्तररेखायां समदेशावस्थितं यद् अश्विन्यादिनक्षत्रेष्ववन्यतमनक्षत्रं दृश्यते तेन तथैव युक्ता नृणामब्दशतं तिष्ठन्तीति ।

“Following is the characteristic of progress of *Kali* age. The *Saptarşi* is a group of 7 stars in the shape of a cart. The first part consists of three stars in arc. They are *Marichi* (Alkaid), *Vasishtha* with his wife (Mizar and Alcor) and *Angirās* (Alioth) from front to back. On the back, as the bed of the cart are 4 stars, *Atri* (Megrez), *Pulatsya* (Phecda), *Pulaha* (Merak), *Krátu* (Dubhe) in North-East, South-East, South-West and North-West direction respectively. Take North-South line passing through the middle of *Pulaha – Kratu,* which rise first and the stars next to them. Whichever *nakşatra* out of *Aşvini* etc. this line meets; it will remain in the same (*nakşatra*) for 100 human years” (Filliozat, 1962).

It is important to note that the original reference in *Vişnu Purāna* does not explicitly mention the exact nature of the pointer. Most interpretations take the pointer as either line passing through first two stars or north-south line passing through centre of the two stars. The ambiguity of the original reference leaves lot of scope for other possible interpretations. As seen above, few commentaries take the pointer to be passing through the centre of the bowl of the big dipper. Also we note that neither şloka nor commentary make explicit mention of any cycle of 2700 years or puts any constraint that the *Saptarşi* should visit each and every *nakşatra*.

Relevance for timekeeping

Like most ancient civilisations, Indians were keen observers of astronomical events. Some non-astronomical event as a chronological pointer seems very uncharacteristic for ancient Indian civilisation. Thus we believe that there should be some astronomical base to the apparently false movement of *Saptarşi* through different *Nakşatras*.

All the civilisations have recognised the bright constellation of *Saptarşi* in some form or another. *Saptarşi*'s passage from east to west was keenly observed by all the ancient civilisations. In most cases, local geographical features like hills, huts, trees etc. make it difficult to observe the stars close to the horizon thus making it difficult to note exact rising or setting time. Further, in any stars apparent path in the night sky, most easily identifiable point is the point at which it is at highest position in the sky. An unaided observer can determine the position of the star at its highest point much more accuratly than at any other position. Consequently, it will be only logical if any civilisation uses event of most easily recognisable constellation in the night sky, i.e. Saptarşi, being at it's highest position in the night sky, for timekeeping purposes.

As observation of any constellation can be hindered by peculiar geography of some place or weather conditions, any observer will like to correlate same time to some other star, in different part of the sky so that atleast one of the two can be safely observed at any given time. As observation of stars close to zenith (exactly on top of our heads) is least likly to be hindered by geographical constraint, observer will tend to note stars close to zenith when Saptarşi are at their highest position in the sky.

At any given point of time, various stars will be at their respective highest positions in the sky. It would be best to choose brightest amongst them. As we will see, the part of *Saptarşi* referred above was in conjunction with the stars Pollux and Castor for most of the neolithic period. Pollux and Castor both being very bright stars, were easily identified as the companion of the *Saptarşi*. Thus it was possible to track any one of the two constellations to keep track of time.

Saptarşi consists of 7 widely separated stars. All of them will not be at their respective highest positions simultaneously. This is the reason why only part of the Saptarşi is mentioned rather than the entire constellation. We will proceed with the traditional interpretation and take the north – south line passing through the center of the first two stars. We have also calculated motion of the pointer using the centre of the bowl interpretation but the results in that case are in direct contradiction with other evidances. We will explain the results in the later section.

Astronomical Considerations

At this point, we will see what are the astronomical factors governing movement of the pointer described above. In order to determine the apparent position of any star in the sky, we have to take into account the multiple movements involved. The north pole of earth was not always pointing towards current pole star, Polaris. As it turns out, the geographic axis of earth itself is revolving in a circle with approximate period of 25,800 years. As it points to different stars at different times, we have had different pole stars in different eras. This motion is called precession of earth's axis. As the position of the pole changes, our North – South orientation also changes and we have to determine new coordinates for all the stars with respect to the then celestial pole.

Also, every star in our sky has some motion with respect to us. In general, we can divide this motion in two parts, one as change in the stars apparent position in the sky and second as change in the stars perpendicular distance from us. The former is called proper motion and the later is called radial motion. Usually the proper motion velocities are small enough to ignore in small time scale calculations. However, they certainly can't be ignored in calculations spanning few thousand years. Further, stars α and η of Ursa Major have proper motion in completely different direction as compared to the proper motion of the other stars of Ursa Major. This effect is more prominient in the past than in the future as Saptarṣi was much closer to the pole star then.

In principle, many other smaller corrections need to be applied to this including precession of earth's perihelion, precession of moon's perigee, effect of position of other planets etc., which all affect the rate of precession of pole in small amounts. We leave these out of our computations as they are much smaller and can be safly ignored (Meeus 1998).

We created a small computer code to test motion of abovementioned pointer. The algorithm for precession was taken from "Astronomical Algorithms" by Meeus (1998). As the accuracy of astronomical observations in the ancient era was probably not better than 1' (1 arc minute or 1/60th of a deg), we recognise that the simple code used would be good enough. We take the current coordinates of the concenred stars and values and directions of their proper motion velocities from “Hipparcos” public catalouge.

We ignore the controversy over correct identification of the *Nakşatras* and go with the traditional definations. As per *Yajurveda* as well as *Brahmagupta* (Subarayappa and Sarma, 1985), *Punarvasu* and *Pūrvā Phālgunī* have two stars each, *Puşya* has one star, *Aşleşā* has 6 stars and *Maghā* has five stars. Consequently, *Pushya* is identified with Praesepe (Bee – hive) cluster in Cancer (M44) and *Aşleşā* with the head of Hydra. It can be noted that M44 appears as a small fuzzy uniform cloud in the sky and many ancient astronomers including Hipparcos and Ptolemy have misidentified it as a star. Both the references quoted above restrict the word *nakşatra* to what we now call principle stars (*Yoga tarakās*) of the nakşatra. Abhyankar (1991) argues that the word *nakşatra* in the Vedic litreture refers to a division in the sky and not just to the principle stars but no such direct and unambiguious reference is found in any of the ancient texts. We believe the nakşatra was probably used to refer the principle stars as well as the division of the sky they belong to. We examine both possibilities and state the result in both the cases.

We calculate positions of 6 *Nakşatras* from *Punarvasu* to *Uttarā Phālguni* for every timestep along with postions of *Saptarşi*, Polaris (the current pole star) and Thuban (α Draconis) which was the pole star around 3000 BC. In case the *nakşatra* is formed by more than 2 stars, we take the westmost and eastmost star of that *nakşatra* as the two endpoints. In order to avoid unnessary computations, the time step was taken as 50 years. The time intervals of interest were further resolved in 10 year time steps.

Results

We determined position of the pointer at various epochs. In the following table, we have tabulated dates at which the pointer was pointing to east most and west most stars of each *nakşatra* as well as dates on which it was midway between two consecutive *Nakşatras*.

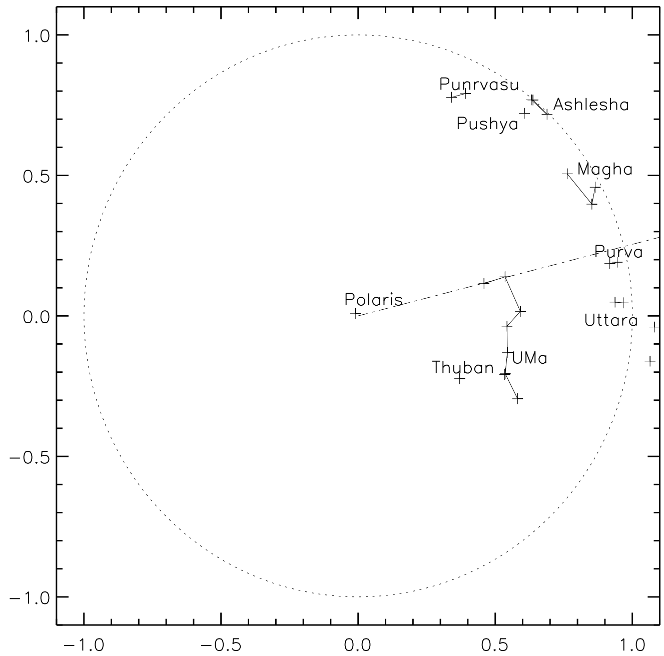

Figure 1: position of pointer for 2000 AD. The centre of each figure is then celestial pole. Dotted line represents celestial equator. The stars are shown by '+' marks. The *Nakşatras* along the equator are marked by their easternmost and westernmost stars.

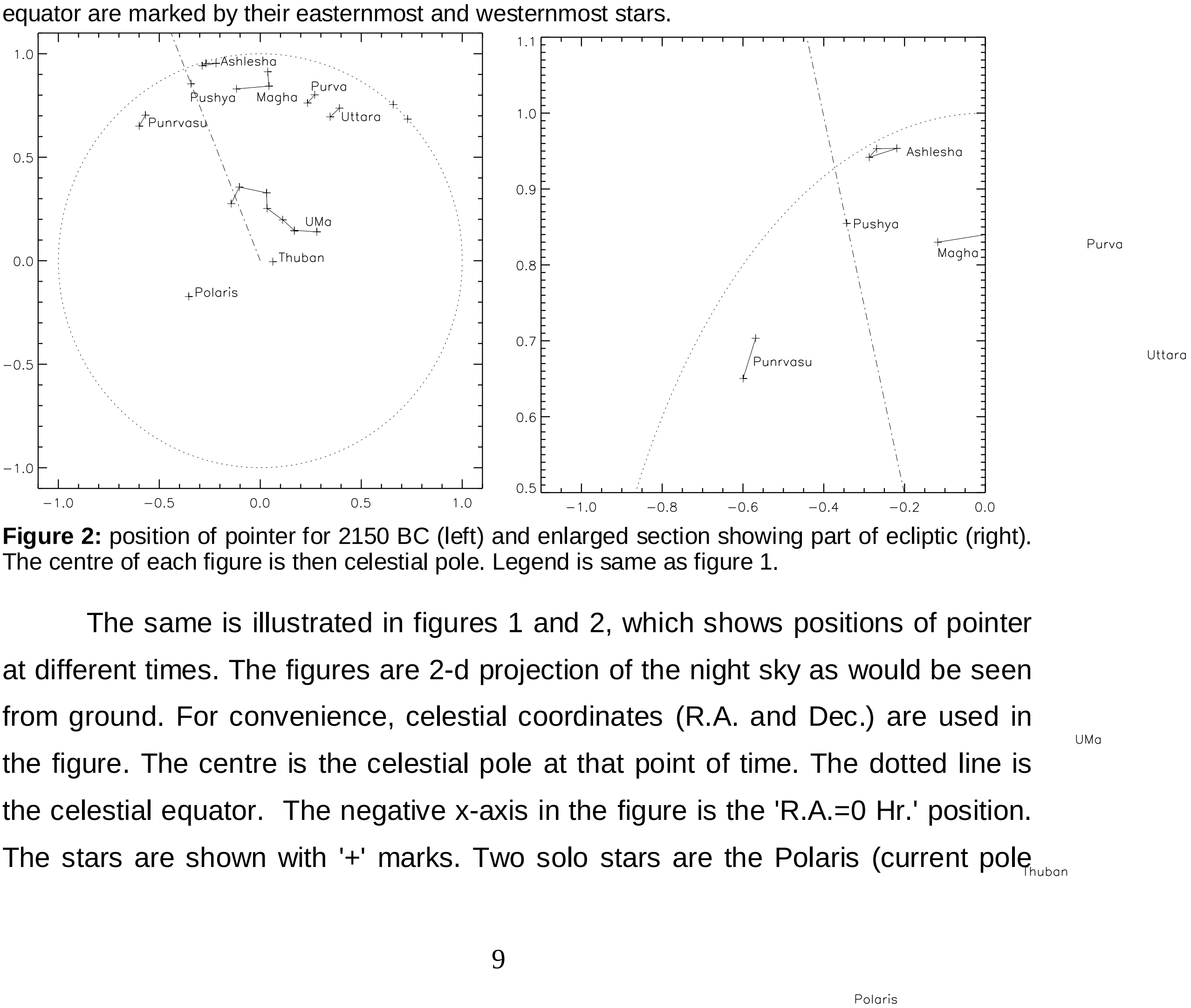

Figure 2: position of pointer for 2150 BC (left) and enlarged section showing part of ecliptic (right). The centre of each figure is then celestial pole. Legend is same as figure 1.

The same is illustrated in figures 1 and 2, which shows positions of pointer at different times. The figures are 2-d projection of the night sky as would be seen from ground. For convenience, celestial coordinates (R.A. and Dec.) are used in the figure. The centre is the celestial pole at that point of time. The dotted line is the celestial equator. The negative x-axis in the figure is the 'R.A.=0 Hr.' position. The stars are shown with '+' marks. Two solo stars are the Polaris (current pole star) and Thuban (α Dra) (Filliozat, 1962). The chariot shaped constellation close to that is Ursa Major. Different Nakşatras shown are joined by straight line. In anticlockwise direction (in increasing RA), they are *Punarvasu, Puşya, Aşleşā, Maghā, Purvā Phālgunī, Uttara Phālgunī* and *Hasta*.

Table 1: Coincidence of pointers with different stars

Pointer at	***Nakşatra***	**Pointer Position**
Castor	*Punarvasu*	Before -8000
Pollux	*Punarvasu*	-4600 ± 25
mid-way		-3000 ± 25
Praesepe cluster	*Puşya*	-2200 ± 05
		-2100 ± 05
mid way		-1950 ± 05
δ Hydrae	*Aşleşā*	-1800 ± 25
ζ Hydrae	*Aşleşā*	-1550 ± 25
mid way		-1250 ± 25
ε leonis	*Maghā*	-1000 ± 25
Regulus	*Maghā*	-0300 ± 25
γ1 leonis	*Maghā*	-0100 ± 25
mid way		+0800 ± 25
δ Leonis	*Purva Phālgunī*	In Future
θ Leonis	*Purva Phālgunī*	In Future

Discussion

We know that Indians designed 27 *Nakşatras* along the ecliptic to denote approximate positions of the moon on each day of the month. This means each *nakşatra* should be placed at the intervals of roughly 13^{o} in the sky. Our simulations show us that at no time since 7900 BC pointer moved with the rate of 13^{o} per century. The highest relative rotation rate (motion of pointer w.r.t. Nakşatras) was in the era before 4000 BC and pointer took roughly 250 – 400 years to span 13^o in the sky during that period. The absolute rotation rate (motion of the pointer alone) was highest when the bowl of the *Saptarşi* was closest to the then celestial pole and the motion through 13^o took pointer slightly less than 500 years. The text, however, clearly mentions that the *Saptarşi* stay in each *nakşatra* for 100 years. Thus, at the first look, the observation looks erronous.

The analysis above assumes that all *Nakşatras* have roughly same size. In practice, this assumption is not true. Some authors argue that Indians first divided ecliptic in 28 (converted to 27 later) equal divisions and then associated principle stars with them (Abhyankar, 1991). Although this task is easily done in modern times, but it would be almost impossible task for a primitive naked eye observer without aid of angle measuring instruments or sky maps. The Nakşatras in their most primitive form must have been limited to just recognisable star groups in vicinity of daily position of the moon. Consequently, they were more likely to be just stars and not divisions of ecliptic initially and likly to be spaced unequally. Thus, some *Nakşatras* are smaller than others. We noticed that the pointer stays in *Puşya nakşatra* for very small period as compared to other *Nakşatras*. We also observed that the motion of the pointer is nonlinear.

Table 1 give us the complete picture. The Beehive cluster (M44) has span of roughly 70 arc minutes. It is clear, that the pointer stay within this cluster , which has been identified with the *Puşya nakşatra* (M44) for 100 years from 2200 BC to 2100 BC. On the other hand, if we assume *Nakşatras* are not just a few stars but are divisions of the sky along ecliptic then pointer stays in each *nakşatra* for much more than 100 years. Shortest stay in that case would be in the *Aşléşā nakşatra* for 700 years (To get idea of periods with this interpretation, take midway postions as begining and end of *Nakşatras*). Thus, if we assume that the *nakşatra* referred are ecliptic divisions and not the principle stars, then the idea of the 100 year transition would be meaningless and just a flight of imagination.

The cycle of precession is of 26,000 years and in principle, we have to verify that this 100 year transition is unique in the entire cycle. But as the Neolithic stage in the human evolution begins only after 7000 BC, we believe prior to 8000 BC, recording such a complicated observation was unlikly.

Conclusions

The *Saptarşi* pointer has very practical significance in naked eye observations. *Saptarşi* being brightest constellation in the sky, it was obviously used for timekeeping during the night. The concept of the pointer was to make sure that in case the view of *Saptarşi* was obstructed, there should be another constellation which was synchronised with the *Saptarşi* at their respective highest positions in the sky. This shows neat methodical structure of observations. During most of the neolithic period (8000 – 3500 BC), this task was very easy as *Saptrashi* were sychronised with *Punarvasu* which comprises of two bright stars both of which are brighter than any one star of the *Saptarşi*. In due course of time, it must have been noticed that earlier calibration of the *Saptarşi* and the *Punarvasu* was no longer true. Probably, to maintain the simplicity, the slight differences in the synchronisations of the *Punarvasu* and the *Saptarşi* were ignored. But observers could no longer ignore it when the *Saptarşi* were nearly in synchronisation with the next *nakşatra*. As a consecuence, attempts were made to gauge rate of rotation of *Nakşatras* w.r.t. the *Saptarşi*.

The *nakşatra* next to the *Punarvasu* is *Puşya* which is a very small *nakşatra*. As the geometrical concepts like angles etc. were probably not developed at that time, rotation was measured simply in per *nakşatra* basis. The simulations above show that indeed *Saptarşi* spanned *Pushya* in roughly 100 years. Thus, very initial attempts to determine rate of rotation of the *Saptarşi* coincided with 100 year transition for a *nakşatra*. This puts a strong case that the mention of the *Saptarşi* transition was a real astronomical observation and not a random fanciful statement. The conventional interpretation of the pointer would mean that this observation was done in around 2200 – 2100 BC. As this period matches well with the conventional knowledge of the *Saptarşi* motion, we believe that the word *nakşatra* in the reference refers to the principle stars only.

The once only occurance of the 100 year *Saptarşi* transition was probably noted by ancient observers, which was generalised by later generations due to misinterpretation. On the other hand it is also possible that the observers who made the initial observation, themselves hastily generalised it into a law. We propose as basic need to gauge rotation rate of the *Saptarşi* won't be forgotten in time span of few generations, the former is more likely. Either way, the generalised law was completely wrong and was of no astronomical significance.

The calenders using the concept of the *Saptarşi* era got popularity in many parts of India as it had provision of naming different centuries. Hence the later astronomers did not counter the law which they realised to be untrue and let chronologists keep using the *Saptarşi* calender. This explains why a calender based on astronomical events was not used by astronomers and was relegated to the domain of historians. Same is the reason why no medivial astronomer mentions then the position of the *Saptarşi* pointer in his texts on astronomy.

This work also puts a limit on date of *Vishnu Purāna*. As this was only once in the known history event, we can say with reasonable confidence that this ṣloka was drafted after 2000 BC. The second line of ṣloka 106, mentions the *Saptarşi* being closer to *Maghā*. A cursory look at the table will show that this will further tighten the limit to 1400 BC (by conventional interpretation). But the *Maghā* question requires detailed analysis and will be taken up in the follow up paper.

At this point, we must note that the mention of the "rise of *Saptarşi*" is a critical detail. At 2200 – 2100 BC era, the declinations of α and β of Ursa Major were both 72^o and 68^o respectivly. This means that their rise could only be observed from the latitudes less than 18^o. To this we can add some grace zone of 2^o – 3^o to take into account imperfect conditions at horizon or other small errors. This would mean that observer was located in peninsular India below tropic of cancer which passes through Gujrat, Madhya Pradesh, Jharkhand and West Bengal. For all the places north of 24^oN the first two stars of the Saptarṣi would be circumpolar and the question of rising won't arise.

In 2200 BC, Indus valley civilisation was in full flourish and was the only dominent civilisation of the region. Many sites of Indus valley civilisation, including bigger townships like Lothal, were located south of tropic of cancer, where rising of the first two stars of *Saptarşi* could be observed. We, thus, believe that the observation of the *Saptarşi* motion was done by people from Indus valley civilisation. This is consistent with earlier work of Vahia (2005), which claimed that the *Nakşatras* themselves originated from Indus valley.

Alternate interpretation that the pointer is passing through centre of the bowl would mean that the observation was done around 3200 – 3100 BC. At that time, the four stars had declinations of 67^o, 65^o, 70^o and 74^o respectivly, which means the observer should be certainly below 25^oN and most probably below 16^oN which passes through Goa and lower Andhra Pradesh. In 3200 BC, Indus valley civilisation was probably just settling. Most Indus valley sites are found in *Indus – Sarasvatī* basin and north of *Vindhyas*. It is less likly that some systematic method of observation would be in place in southern India. Thus, we conclude that the centre of bowl interpretation is probably not correct.

Thus, we conclude that, the observation of 100 year the *Saptarşi* transition was done in 2200 – 2100 BC and most probably by Indus valley civilisation. This piece of information got itself included in the Sanskrit litreture at some later date. Over the generations the original context of the observation was forgotton. It was used as calendar and got mention in *Puranas* as an important astronomical observation.

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