Possible period of the design of Nakshatras and Abhijit

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Abstract

The Nakshatras were designed to keep track of the moon's path in the night sky. The ancient literature does not give the exact position of these Nakshatras but there are many stories associated with each Nakshatrā. There are a total of 27 Nakshatras spanning the night sky and the Moon takes and average of one day to cross each Nakshatra. The earliest mention of Nakshatras is in Vedas. Some of the Vedic literature mentions 28 Nakshatras. The Nakshatra Abhijit gets dropped in the later on documents. However, as per the present association of stars with these Nakshatras, several of them are as far as 25º away from the ecliptic where as Moon travels only about 5º on either side of the ecliptic. The possibility that in the remote past the ecliptic could have been 25º north to the present is not likely. We study the sky pattern from 3500 BC to 2005 AD and show that the Moon's path was closest to the maximum number of Nakshatrās around 3000 BC. To account for 28 Nakshatrās we also looked for the likelihood that a transient star may have existed in the region of Abhijit around the time when the Nakshatrās were defined. We did find a Supernova of apparent magnitude brighter than the brightest star that must have been visible in the region where Abhijit was supposed to be around 3000 BC. We therefore suggest that the Nakshatrās were defined around 3000 BC.

1. Introduction

The ancient Indian calendar dates back several thousand years and the relevant literature has been extensively collated in a major commentary called the *Indian Calendar*, by Sewell and Dikshit (1986). It uses the concept of *Nakshatra* that corresponds to a group of stars along the path of the Moon (see e.g. Bhujle and Vahia, 2006). These are also called star mansions or Asterisms. The concept is that moon visits these mansions in his trajectory around earth. These are used to keep time by tracking the path of the moon and calculate the phase of the moon. Elsewhere Bhujle and Vahia (2005) have discussed the manner of calculation of tithis, which shows that in later periods, tithis are calculated based on some excellent analytical work of Varahmihira. Since then, the location of Moon in a particular Nakshatrā is a point of interest only to sky watchers while the calendar makers have relied on the analytical formulation, which is periodically synchronised with observations. However, in early times direct observations must have played a critical path in keeping track of the days of a month.

Indian Calendar is called *Pancāng*. Nakshatras play an important role in this calculation. The time, which the Moon requires to travel over the 27th part of the ecliptic, is called 'Nakshatrā'. During the traversal of Moon around the Earth the Moon is close to some of the fixed stars. Twenty-seven groups of stars that fall on the path of the Moon are identified. In 27.3 days, that is, Moon's one sidereal revolution, Moon travels through 27 stars that were said to form the 27 *Nakshatrās*. Hence, on an average Moon travels one Nakshatra everyday. The star or star group, which is closest to the Moon on its path, is called Moon’s *Nakshatrā*. Note that the synodic period of the Moon (from Full/New moon to the next full/new moon) is 29.5 days and the Lunar month is defined by this period. Hence in one synodic (normal) month, the moon will travel 27 Nakshatrās and repeat two more. Approximately 12 synodic months make a year. The twelve months were named after the stars at which full moon occurs and these are *Chaitra*, *Vaishākha, Jyeshta, Aśādh, Shrāvań, Bhadrapad, Ashvin, Kārtik, Māragashirsh, Pushya, Māgha, Phālgun*. Typically alternate stars with some skips refer to month names and hence accommodate 27 stars corresponding to nearly 360 degrees motion of Sun in a solar year.

The names of Nakshatrās and their co ordinates are given in Table 1 below.

Table 1: Names of Nakshatrās from Atharvana Veda, the stars associated with them in modern catalogues (Mahajani 2005) and their current coordinates

Nakshatrās	**Principal star**	**RA**	**Dec**
Ashvinī	β Arietis	1h 55m	20. 48'
Bharanī	41 Arietis	2h 50m	27. 17’
Krittikā	η Tauri	3h 47m	24. 6'
Rohinī	α Tauri	4h 36m	16. 31'
Mrigashīrsha	λ Orionis	5h 35m	9. 56'
Ārdrā	α Orionis	05h 55m	7° 24'
Punarvasu	β Geminorum	7h 45m	28. 2'
Pushya	δ Cancri	08h 45m	+18° 7'
Āshleshā	zeta Hydra	8h 55m	5. 55'
Maghā	α Leonis	10h 8m	11. 58'
Pūrva Phalgunī	δ Leonis	11h 14m	20. 31'
Uttara Phalgunī	β Leonis	11h 49m	14. 34'
Hastā	δ Corvi	12h 30m	-16. -32’
Chitrā	α Virginis	13h 25m	-12. -10’
Svātī (Nistya)	α Bootis	14h 15m	+19. 9'
Vishākhā	α2 Librae	14h 51m	-17. -2’
Anurādhā	δ Scorpii	16h 0m	-23. -37'
Jyeshtha	α Scorpii	16h 29m	-27. -26’
Mūla	λ Scorpii	17h 34m	-37. 6'
Pūrva Ashādhā	δ Sagittarii	18h 21m	-29. 49'
Uttara Ashādhā	σ Sagittarii	18h 55m	-27. -18'
Abhijit	***Probable supernova***		
Shravana	α Aquilae	19h 51m	+8. 52'
Danishthā	β Delphini	20h 37m	14. 36'
Shatabhishā	λ Aquarii	22h 52m	-7° 32'
Pūrva Bhādrapadā	β Pegasi	23h 04m	28. 6'
Uttara Bhādrapadā	γ Pegasi	00h 13m	+15. 12'
Revatī	η Piscium	1h 31m	15. 21'

The earliest reference of the names of Nakshatrās appears in Yajur Veda.

2. Identification of Nakshatras

Path of the moon in the sky is very sensitive to various perturbations such as tides and the exact relative separation of Sun, Moon etc. In order to calculate the position of the moon accurately for a given instant, it is necessary to take in to account hundreds of periodic terms in moon's longitude, latitude and distance. Jean Meeus (1998), takes into account the most important periodic terms. The accuracy of the result is 10´´ in the longitude of the moon and 4´´ in its latitude for the period of ±50 years from the current era. We assume that the formula doesn't give more than 1° of error in the path of the moon when used backwards till 3500 BC.

The software programme Sky Map Pro 11 (2006) includes these corrections and we have used it to generate the sky pattern for a given time. This program gives graphic view of the sky from 4713 BC to 9999 AD. The program takes into account the changes in coordinates of the stars due to precession of earth. The author of the program uses Jean Meeus' Astronomical Algorithms.

We determined the RA and Declination of the Nakshatrās and Moon around 3500 BC, 3250BC, 3100 BC, 3000 BC, 2750 BC, 2500 BC, 2200 BC, 2000 BC, 1500 BC, 1000 BC, 500 AD and 2000 AD. The best amplitude (declination) match of the Nakshatrās sine curve was around the year 3000 BC
(Bhujle and Vahia, 2006). We calculated the difference in amplitude (Declination values) between Moon's path and Nakshatrās best-fit line for the same Right Ascension. We plotted a graph of Moon's average value of Declination(Dec) Vs Year.

Figure 1: Average Declination difference between the Moon and the Nakshatrās Vs Year

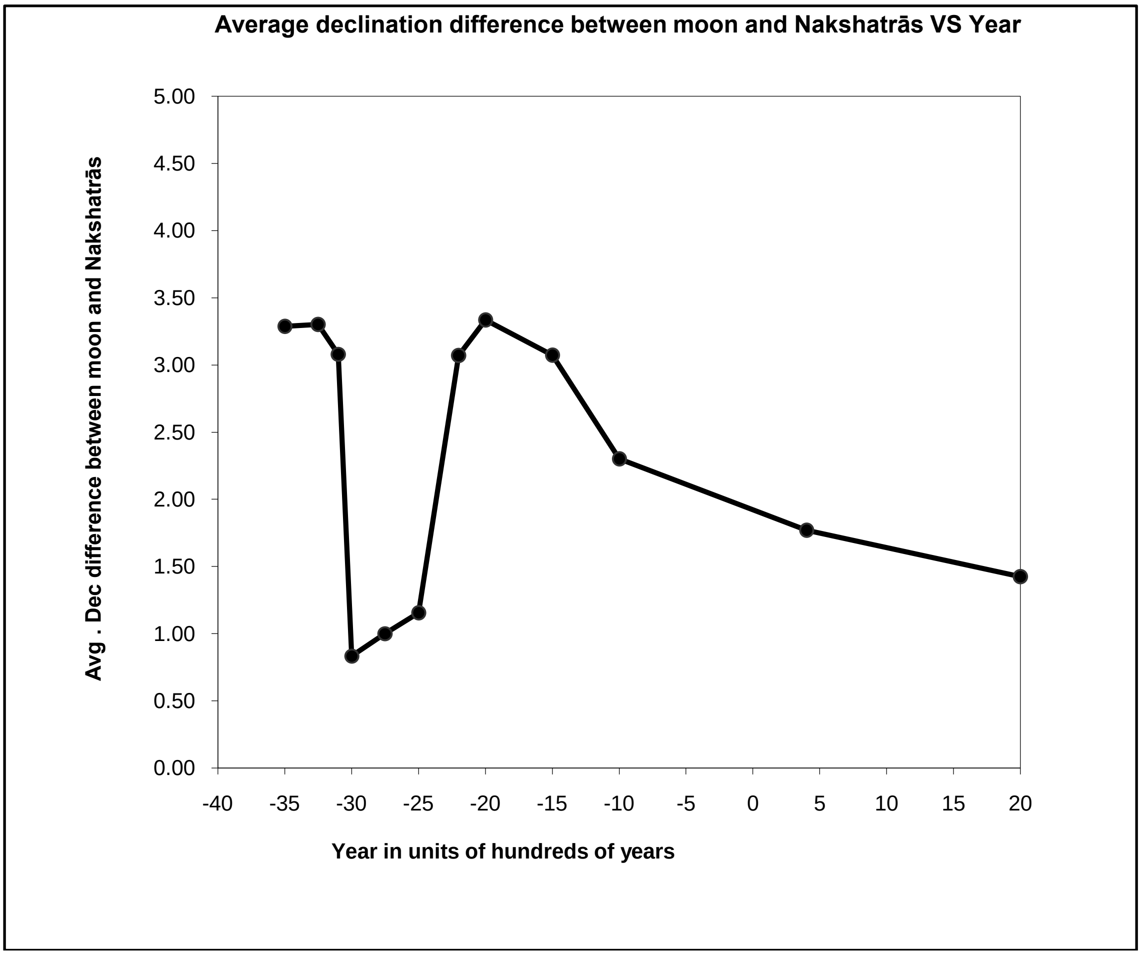

Figure 2: Graph of the radius of supernova remnants and their age from Guseinov et al. (2003, 2004 a,b). The best-fit line with a reduced χ^2 of 0.84 is given by the equation radius = 0.0016 $\times$ age.

It can be seen from the figure that the change in mean declination has changed significantly with time and was at its minimum around 3000 BC. We therefore suggest that the Nakshatrās were designed during this period.

3. Possibility of Abhijit as a Supernova

Yajur Veda and Atharvana Veda both mention Abhijt as a Nakshatrā after Uttara Ashādhā and before Shravana. The principal star of Uttara Ashādhā is σ Sagittarii and that of Shravana is α Aquilae. Both Nakshatrās coordinates are mentioned in Table 2.

Table 2 : Co ordinates of Uttara Ashādhā and Shravana

Nakshatrā	Bayer Identity	Magnitude	RA	Declination
Uttara Ashādhā	σ Sagittarii	2.05	18h 55m	-27. -18'
Shravana	α Aquilae	0.93	19h 51m	+8. 52'

Looking at the above table we understand that the RA of Abhijit has to be greater than 18h 55m and less than 19h 51m. The deletion of this Nakshatrā from the list in later on documents makes it likely that there was a star (supernova) around the period 3000 BC in the region between RA 19 hours to 20 hours, which has since become too faint to be seen. A similar suggestion has also been made by Iyenger (2006). Supernova Remnants which are explosive residues of dead stars that can remain bright for several years and visible for another few hundred years before fading into oblivion seem to be ideal candidates for the same. However, powerful telescopes can see even faint remnants and their catalogues are available in literature. We searched for supernova remnants in the region of the inferred location of Abhijit. To carry out the exercise we listed (Table 3) possible supernovae in the region of 19-20 hours RA from Green's catalogue (Green 2003).

Table 3: Possible supernovae in the region of declination of 19-20 hours

Sr No	SNR	Dist. in kpc	Angular size in arcmin	RA _HH	RA_MM	RA_SS	Dec_DD	Dec_MM
1.	G45.7-0.4	6.7	22	19	16	25	11	9
2.	G46.8-0.3	7	13	19	18	10	12	9
3.	G54.1+0.3	6	1.5	19	30	31	18	52
4.	G55.7+3.4	7	23	19	21	20	21	44
5.	G57.2+0.8	11.7	12	19	34	59	21	57
6.	G59.5+0.1	11	5	19	42	33	23	35
7.	G59.8+1.2	9.1	16	19	38	55	24	19

The age of these supernova remnants are not available in the literature. However, the radius of the supernova remnant is proportional to its age and one can determine the age of the supernova remnant by its size based on the formulation of Imashennik (2000) and from the data which gives the ages of about 45 supernovae by Guseinov et al. (2003, 2004 a,b) to create a calibration curve.

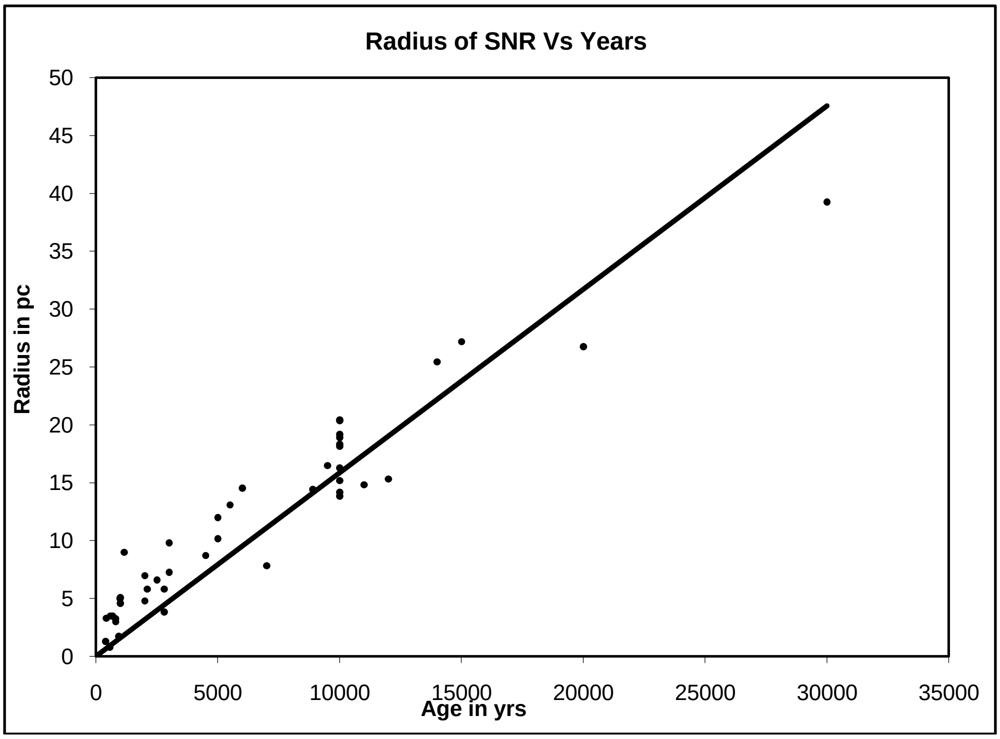

Figure 3: Expansion rate of Supernovae

Table 4: Age of the supernovae in the region of 19 - 20 hours RA

Sr No	**SNR**	**Distance D in kpc**	**Angular size φ in arcmin**	**Radius R=0.5Dφ in pc**	**SNR age in years**	**Apparent magnitude in the night sky**
1.	G45.7-0.4	6.7	22	21.43	13,397	-5.5
2.	G46.8-0.3	7.0	13	13.23	8,271	-5.4
3.	G54.1+0.3	6.0	1.5	1.31	818	-5.7
4.	G55.7+3.4	7.0	23	23.41	14,633	-5.4
5.	G57.2+0.8	11.7	12	20.42	12,760	-4.3
6.	G59.5+0.1	11.0	5.0	8.00	5,000	-4.4
7.	G59.8+1.2	9.1	16	21.17	13,233	-4.8

Amongst all these supernova remnants, most are of age greater than 10,000 years and so we ignore them. Similarly the supernova that went of 818 years ago is too recent. Hence we have two candidate supernova remnants at 5,000 and 8,271 years ago. We then estimate the apparent magnitude of all these remnants in the night sky using the standard formulation (Dutkevitch, 1998).

We assume the standard value for the absolute magnitude supernova to be – 19.6. Using above formula we get the magnitude of about – 5.4 and – 4.4 for the supernova remnants of 8271 years ago and 5000 years ago respectively. Any of these stars could have served as the guest star. However, 8271 years ago seems to be too early a date for the design of the Nakshatrās and we propose that the supernova remnant G9.5+0.1 seems to be the most likely candidate for Abhijit.

4. Conclusion

We have investigated the path of the Moon over 5 millennia for its proximity to the maximum number of Nakshatrās. We find that around 3000 BC the Moon seems to have the path of closest approach to the Nakshatras. We then investigate the initial reference to the 28th Nakshatrā, the Abhijit that is deleted in later literature. We suggest that a supernova remnant in the neighbourhood of the originally proposed location of Abhijit. We find that a supernova G59.5+0.1 has the correct age of 5000 years before present to satisfy the condition that it would have been called the Abhijit Nakshatrā in the initial period and would have been deleted in the later revision in the period of Aryabhata and Varahmihira (fourth or fifth century AD).

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