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# Could the "case for Revising the Date of *Vedāṅga Jyotiṣa*" be flawed?

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## Abstract

In "A case for Revising the Date of *Vedāṅga Jyotiṣa*" Narahari Achar (Indian J Hist Sci 35(3):173–183, 2000) has proposed a date of 1800BCE for the composition of *Vedāṅga Jyotiṣa* and the star δ Cap as *yogatārā* of *nakṣatra Śraviṣṭhā*. The study presented here demonstrates that neither a unique epoch of *Vedāṅga Jyotiṣa* nor a unique *yogatārā* of *nakṣatra Śraviṣṭhā* can be determined with the criteria proposed by Narahari Achar. Moreover, the proposed *yogatārā* does not satisfy the configuration of celestial objects at the start of a *yuga* described in *Vedāṅga Jyotiṣa*.


**Keywords** *Vedāṅga Jyotiṣa* · Vedic chronology · *Yogatārā* · β Delphini · δ Capricorni

### Abbreviations

*AB* *Aitareya Brāhmaṇa*
*KS* *Kāṭhaka Saṃhitā*
*KB* *Kauṣītaki Brāhmaṇa*
*MS* *Maitrāyaṇī Saṃhitā*
*TB* *Taittirīya Brāhmaṇa*
*RV* *Ṛgveda Saṃhitā*
*RJ* *Vedāṅga Jyotiṣa*; *Ṛgvedic* recension
*YJ* *Vedāṅga Jyotiṣa*; *Yajurvedic* recension

## Introduction

*Vedāṅga Jyotiṣa* is the oldest known mathematically codified calendric text of South Asia. The date of this text is, therefore, of crucial importance in the examination of history of mathematics and astronomy in South Asia. The first attempt to date *Vedāṅga Jyotiṣa* was made by Dīkṣit (1969) more than 100 years ago. Dīkṣit based his date of *Vedāṅga Jyotiṣa* on the interpretation of verses *RJ*.5-6 and *YJ*.6-7. The same approach was followed by Kuppanna Sastry (1984). The verses *RJ*.5 and *YJ*.6 state that "when the Sun and the Moon occupy the same region of the zodiac together with the asterism of *Śraviṣṭhā* at that time begins the *yuga*, and the (synodic) month of *Māgha*, the (solar seasonal) month called *Tapas*, the bright fortnight (of the synodic month, here *Māgha*), and their northward course (*uttaram ayanam*)" Kuppanna Sastry (1984). Both Dīkṣit and Kuppanna Sastry arrive at a date between 1500BCE and 1100BCE. Both these scholars assumed that the star β Delphini was the *yogatārā* of the *nakṣatra Śraviṣṭhā*. This identification of the *yogatārā* was from Burgess (1935), who identified *yogatārās* given in *Sūryasiddhānta*. This is a text of the Siddhānta period and the *yogatārās* identified during this period may not be the same as those identified during the Vedic period.

This date has been contested for over 100 years. The currently accepted date (particularly by western scholars) of *Vedāṅga Jyotiṣa* is the last half of first millennium BCE (Pingree, 1970, 1973). This date is based on the astronomy and language of *Vedāṅga Jyotiṣa*. There are similarities between aspects of *Vedāṅga Jyotiṣa* and Assyrian/late Babylonian astronomy. There was also a possible connection between these two astronomies (or accurately a connection between the cultures of Mesopotamia and South Asia) during the Achaemenid occupation of north-western South Asia from 513 BCE to 326BCE. The implication being that the mathematical astronomy of *Vedāṅga Jyotiṣa* was transmitted to South Asia from Mesopotamia and there is no original contribution by South Asians to *Vedāṅga Jyotiṣa*. This and such reasoning implicitly deny independent parallel or sequential developments of a subject at multiple centres. Moreover, the Achaemenid conduit is irrelevant since there was exchange of goods, ideas and people between South Asia and the Middle East long before and after the Achaemenid rule. The complete absence of any Mesopotamian words in *Vedāṅga Jyotiṣa* or in any Vedic text argues strongly against any Mesopotamian influence

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let alone borrowing by South Asians from Mesopotamian astronomy. The contention that *Vedāṅga Jyotiṣa* was transmitted to South Asia during Achaemenid occupation is just a restatement of the now discredited nineteenth and early twentieth century belief that conquest and subjection were the engines of change and progress.

The reconstructed evolution of Sanskrit literature from early Vedic to Classical places the linguistic form of *Vedāṅga Jyotiṣa* in the last half of first millennium BCE. It is possible that the text available now was composed in the last half of first millennium BCE. However, the Vedic texts were frequently reworked and the content of *Vedāṅga Jyotiṣa* may be much older, not unlike Euclid's *Elements* or MULAPIN (Hunger & Pingree, 1989).

A re-evaluation of the date of *Vedāṅga Jyotiṣa* is essential given the large discrepancy in the date obtained from internal evidence and that inferred from circumstantial evidence.

Narahari Achar (2000) has re-examined the method of Dīkṣit and Kuppanna Sastry; he has correctly pointed out, as noted earlier, that the stars selected as *yogatārās* by the medieval astronomers my not be the same as those selected by the Vedic sky-watchers and secondly β Delphini (and about eleven other *nakṣatras* and their *yogatārās*) is quite far from the ecliptic. According to the Vedic texts the moon moves in the vicinity of the *nakṣatras* (e.g. *RV*. X.85.2); Narahari Achar, therefore, asserts that all *nakṣatras* should be within ± 10° of the ecliptic. This is a conjecture by Narahari Achar as he has provided no textual evidence. Narahari Achar has reinterpreted the passage "the Sun and the Moon occupy the same region of the zodiac together with the asterism of *Śraviṣṭhā* at winter solstice" to mean that at the epoch of *Vedāṅga Jyotiṣa* the asterism of *Śraviṣṭhā* should be at right ascension of about $18^h$ (the right ascension of the Sun at winter solstice) and no more than ± 10° from the ecliptic. He has used the planetarium software SkyMap Pro to show that a $2.83^m$ star, δ Capricorni (Ra:21°47$^m$ 02$^s$.4; Dec: − 16°07$^m$38$^s$) satisfies these conditions around 1800BCE. He has proposed δ Cap as the *yogatārā* of *nakṣatra Śraviṣṭhā* and 1800BCE as the most likely epoch of *Vedāṅga Jyotiṣa*. This author has made the same mistake as that made repeatedly by almost all analysts over last almost 200 years in the interpretation of astronomical references in the Vedic text; namely, the interpretation is based entirely on comparison of coordinates (a concept that would not have been known to the Vedic sky-watchers) without addressing the issue of observations. The Vedic sky-watchers did not have the benefit of a list of stellar coordinates nor did they have access to planetarium software. *They would have relied entirely on naked eye observations.* This is particularly pertinent in the interpretation of verses *RJ*.5-6 and *YJ*.6-7 of *Vedāṅga Jyotiṣa* as these verses describe exactly the configuration of the Sun, Moon and the *nakṣatra* at the start of a *yuga*. *Thus an attempt to identify the yogatārā of nakṣatra Śraviṣṭhā must ascertain that this star conforms to the sky configuration described in RJ.5-6 and YJ.6-7.*

## Stars around winter solstice

In this study the method of Narahari Achar using his criteria is extended to all stars and to a number of epochs in the Vedic Period. The study also examines if the Vedic sky-watchers would have been able to verify that the stars that satisfy these criteria were visible in the same region of the sky as the Sun at or around winter solstice, as described in verses *RJ*.5-6 and *YJ*.6-7. This is not an attempt to identify the *yogatārā* of *nakṣatra Śraviṣṭhā* or that of any other *nakṣatra*. Therefore, various methods for identifying *yogatārā* of *nakṣatras* have not been considered here.

In the present analysis four randomly selected epochs in the Vedic Period are considered and all stars that occupy the same region of the sky as the Sun at winter solstice at these four epochs, that is all stars around $18^h$ and within ± 10° of the ecliptic, are identified. In the list of *yogatārās* most stars are brighter than $4^m$ and the present study is limited to the 513 stars in the sky which are brighter than $4^m$. In Table 1 are given stars between 2000BCE (chosen arbitrarily) and 500BCE (the putative date of the end of the Vedic era) that satisfy the conditions specified by Narahari Achar i.e. right ascension of $18^h \pm 30^m$ and ecliptic latitude of ± 10°. It can be seen from Table 1 that δ Cap is close to $18^h$ from 2000BCE to 1500BCE in agreement with Narahari Achar's analysis. At 1000BCE δ Cap will be at right ascension of $18.9^h$ not very far from the position of the Sun at winter solstice, but at 500BCE it will be at right ascension of $19.4^h$, more than $1^h$ away from the position of the Sun at winter solstice. There are a number of other bright stars, including β Aqr, the star proposed as a possible *yogatārā* of *nakṣatra Śraviṣṭhā* by Abhyanker (1991), also at $18^h \pm 30^m$ and within ± 10° of the ecliptic at almost all epochs up to 500BCE. Although these stars are not as bright as δ Cap, their brightness is entirely within the range of brightness of stars currently accepted as *yogatārās*. By Narahari Achar's criteria, any one of these stars could be the *yogatārā* of *nakṣatra Śraviṣṭhā* in the period from 2000BCE to 500BCE.

For corroboration of δ Cap as the *yogatārā* of *nakṣatra Śraviṣṭhā*, Narahari Achar has shown (with the aid of SkyMap Pro) that the first full moon after winter solstice of 1752BCE (his fiducial epoch) is in the *nakṣatra Maghā* (*yogatārā* α Leonis) as required by *RJ*.5-6 and *YJ*.6-7. Note that this *yogatārā* is from the same list that identified β Delphini as the *yogatārā* of *nakṣatra Śraviṣṭhā* i.e. this identification is made during the Siddhāntic Period and this may not be the identifications of the Vedic sky-watchers. For each epoch in Table 1 the location (in ecliptic longitude and latitude) of the first full moon after winter solstice is given

**Table 1** Stars at right ascension $18^h \pm 30^m$ ($18 \pm 0.5^h$) and ecliptic latitude of $\pm 10°$

| Star ID | α(2000) δ(2000) | mag | RA(epoch) | l b | AWS Ma | BWS Ea |
|---|---|---|---|---|---|---|
| 2000BCE | | | | | | |
| δ Cap | 21 47 02.4 − 16 07 38 | 2.83 | 17.8 | 268.1 − 2.2 | − 22 4 | 26 4 |
| γ Cap | 21 40 05.4 − 16 39 44 | 3.67 | 17.7 | 266.4 − 2.2 | − 22 6 | 30 6 |
| β Aqr | 21 31 33.5 − 05 34 16 | 2.89 | 17.8 | 268.1 9.0 | − 16 5 | 19 5 |
| 1500BCE | | | | | | |
| δ Cap | 21 47 02.4 − 16 07 38 | 2.83 | 18.3 | 275.0 − 2.3 | − 30 4 | 18 4 |
| γ Cap | 21 40 05.4 − 16 39 44 | 3.67 | 18.2 | 273.3 − 2.2 | − 30 6 | 22 6 |
| ζ Cap | 21 26 40.0 − 22 24 40 | 3.74 | 17.8 | 268.4 − 6.6 | − 29 5 | 31 5 |
| ε Aqr | 20 47 40.5 − 09 29 44 | 3.77 | 17.5 | 263.2 8.4 | − 13 6 | 26 6 |
| β Aqr | 21 31 33.5 − 05 34 16 | 2.89 | 18.3 | 274.9 8.9 | − 23 5 | 11 5 |
| 1000BCE | | | | | | |
| δ Cap | 21 47 02.4 − 16 07 38 | 2.83 | 18.9 | 281.9 − 2.4 | − 39 4 | 10 4 |
| ζ Cap | 21 26 40.0 − 22 24 40 | 3.74 | 18.4 | 275.3 − 6.7 | − 37 5 | 23 5 |
| γ Cap | 21 40 05.4 − 16 39 44 | 3.67 | 18.7 | 280.1 − 2.3 | − 39 6 | 14 6 |
| β Aqr | 21 31 33.5 − 05 34 16 | 2.89 | 18.8 | 281.8 8.9 | − 30 5 | 5 5 |
| ε Aqr | 20 47 40.5 − 09 29 44 | 3.77 | 18.0 | 270.1 8.4 | − 21 6 | 18 6 |
| 500BCE | | | | | | |
| δ Cap | 21 47 02.4 − 16 07 38 | 2.83 | 19.4 | 288.8 − 2.4 | − 47 4 | 2 4 |
| ε Aqr | 20 47 40.5 − 09 29 44 | 3.77 | 18.4 | 277.0 8.3 | − 28 6 | 12 6 |
| α02 Cap | 20 18 03.2 − 12 32 41 | 3.58 | 17.9 | 269.1 7.2 | − 20 6 | 20 6 |
| β01 Cap | 20 21 00.6 − 14 46 52 | 3.08 | 17.9 | 269.3 4.9 | − 20 5 | 20 5 |

α(2000) Right ascension (h:m:s)
δ(2000) Declination (d:m:s)
RA(epoch) Right ascension at the epoch (h:m:s)
l Ecliptic longitude (deg)
b Ecliptic latitude (deg)
AWS day after winter solstice
BWS day before winter solstice
Ma altitude at dawn (deg)
Ea altitude at dusk (deg)

Location in *Madhyadeśa* (Delhi, 77° 12′ E; 28° 35′ N; altitude 229 m)

in Table 2 along with the ecliptic coordinates of all bright stars (brighter than $4^m$) with ecliptic latitude of $\pm 10°$ and those separated from the Moon by no more than 10°. As can be seen from Table 2, α Leo (and some other stars) is within 10° of the first full moon after winter solstice at all epochs from 2000BCE to 1000BCE. At 500BCE α Leo is slightly further than 10° from the full Moon. Not all stars in Table 2 will be visible to a casual observer. In column six

**Table 2** Stars in the vicinity of the first full moon after winter solstice. Stars within ecliptic latitude ± 10° and within the 10° of the Moon

| Star ID | α(2000)<br>δ(2000) | mag | l<br>b | sep | lmag |
|---|---|---|---|---|---|
| 2000BCE | | | | | |
| Full moon ecliptic: longitude 104.3° latitude + 3.7° | | | | | |
| ρ Leo* | 10 32 48.6<br>+ 09 18 23 | 3.87 | 101.0<br>− 0.11 | 5 | 1.7 |
| α Leo | 10 08 22.3<br>+ 11 58 01 | 1.40 | 94.5<br>0.16 | 10 | 2.7 |
| θ Leo* | 11 14 14.4<br>+ 15 25 46 | 3.35 | 107.9<br>9.48 | 7 | 2.2 |
| γ01 Leo* | 10 19 58.4<br>+ 19 50 28 | 1.98 | 94.2<br>8.50 | 11 | 2.6 |
| 1500BCE | | | | | |
| Full moon ecliptic: longitude 110.9° latitude − 1.0° | | | | | |
| ρ Leo* | 10 32 48.6<br>+ 09 18 23 | 3.87 | 107.9<br>− 0.06 | 3 | 0.7 |
| α Leo | 10 08 22.3<br>+ 11 58 01 | 1.40 | 101.3<br>0.20 | 9 | 2.6 |
| 1000BCE | | | | | |
| Full moon ecliptic: longitude 105.0° latitude − 4.8° | | | | | |
| ο Leo* | 09 41 09.0<br>+ 09 53 32 | 3.52 | 102.6<br>− 4.00 | 3 | 0.8 |
| ρ Leo* | 10 32 48.6<br>+ 09 18 23 | 3.87 | 114.7<br>− 0.02 | 11 | 3.1 |
| α Leo | 10 08 22.3<br>+ 11 58 01 | 1.40 | 108.2<br>0.25 | 6 | 3.5 |
| η Leo* | 10 07 19.9<br>+ 16 45 45 | 3.41 | 106.2<br>4.64 | 9 | 3.1 |
| 500BCE | | | | | |
| Full moon ecliptic: longitude 101.5° latitude − 4.4° | | | | | |
| ο Leo* | 09 41 09.0<br>+09 53 32 | 3.52 | 109.5<br>− 3.9 | 8 | 2.7 |
| δ Cnc* | 08 44 41.0<br>+ 18 09 15 | 3.94 | 94.0<br>− 0.19 | 9 | 2.7 |
| α Leo | 10 08 22.3<br>+ 11 58 01 | 1.40 | 115.1<br>0.29 | 14 | 2.8 |

α(2000) Right ascension (h:m:s)
δ(2000) Declination (d:m:s)
l Ecliptic longitude (deg)
b Ecliptic latitude (deg)
sep Separation between the full moon and the star (deg)
lmag Limiting magnitude: stars fainter than this limit will be lost in the glare of the Full Moon. Identified by *

Location in *Madhyadeśa* (Delhi, 77º 12′ E; 28º 35′ N; altitude 229 m)

of Table 2 is given the limiting magnitude at the position of the star near a full Moon (Krisciunas & Schaefer, 1991). Only stars brighter than this limiting magnitude will be visible to a human observer. The stars that will be lost in the glare of the full Moon have been identified with an asterisk in Table 2. From 2000BCE to 500BCE the bright star α Leo will be the only star visible in the immediate vicinity of the first full Moon after winter solstice and the Moon can be considered to be in the *nakṣatra Maghā* at all epochs during the Vedic Period.

As a further corroboration, Narahari Achar has shown that at 1752BCE the right ascension of star ζ Hydrae, the *yogatārā* of *nakṣatra Āśleṣā* (also selected from the list of *yogatārās* identified in Siddhāntic Period) is close to $6^h$ (or ecliptic longitude of 90°), that is, it is in the same region of the sky as the Sun at summer solstice. In other words, at summer solstice the Sun is in the *nakṣatra Āśleṣā*; as required by *RJ*.5-6 and *YJ*.6-7. In Table 3 are shown all bright stars (brighter than $4^m$) at $6^h \pm 30^m$ (or at ecliptic longitude of about 90°) and ecliptic latitude of ± 10 for four epochs between 2000BCE and 500BCE. Note that the stars close to the position of the Sun at summer solstice are similar to the stars close to the full moon after winter solstice; this is to be expected. The full moon at winter solstice or soon after winter solstice will occupy a region of the sky similar to that occupied by the Sun at summer solstice. At all epochs in Table 3 the star ζ Hya (*yogatārā* of *nakṣatra Āśleṣā*) is close to the position of the Sun at summer solstice, that is, the Sun is in the *nakṣatra Āśleṣā* during the entire Vedic Period. Narahari Achar has not address the question of how the Vedic sky watchers would have determined the stars in the vicinity of the Sun at summer solstice. One possibility is that they would have identified stars in the vicinity of the full Moon at winter solstice; these stars would be in the vicinity of the Sun at summer solstice for reasons described earlier. Only stars not lost in the glare of the full Moon would be visible.

## Discussion

The verses *RJ*.5-6 and *YJ*.6-7 define the day of the start of a new *yuga*. This day was of crucial importance to the Vedic people for apart from its calendrical significance it was also the first day of the annual sacrificial cycle of *Gavām ayana* (cows' walk/course). In the interpretation of Vedic texts, it is essential to trust the word of the *Vaidīkas* and the statement (in *RJ*.5-6 and *YJ*.6-7) "when the Sun and the Moon occupy the same region of the zodiac together with the asterism of *Śraviṣṭhā* at that time begins the *yuga*" suggests (certainly to the author) that the Vedic sky-watchers had observed the stars of asterism of *Śraviṣṭhā* in the vicinity of the Sun at the start of a *yuga*. The only time a star can be seen to occupy the same region of the sky as the Sun is at heliacal rising and setting of the star. The Vedic sky-watchers were familiar with heliacal raising and setting of stars (*TB*.1.5.2.1, Subbarayappa & Sarma, 1985). At astronomical twilight, the Sun is between 18° and 12° below the horizon and the sky

**Table 3** Stars around ecliptic longitude 90 ± 10° (right ascension $6^h$, Sun at summer solstice) and latitude 0 ± 10°

| Star ID | α(2000)<br>δ(2000) | mag | l<br>b | sep |
|---|---|---|---|---|
| 2000BCE | | | | |
| ο Leo | 09 41 09.0<br>+ 09 53 32 | 3.52 | 88.9<br>− 4.11 | 4 |
| α Leo | 10 08 22.3<br>+ 11 58 01 | 1.40 | 94.4<br>0.16 | 4 |
| γ01 Leo | 10 19 58.4<br>+ 19 50 28 | 1.98 | 94.1<br>8.50 | 9 |
| η Leo | 10 07 19.9<br>+ 16 45 45 | 3.41 | 92.5<br>4.54 | 5 |
| ζ Hya | 08 55 23.6<br>+ 05 56 44 | 3.10 | 79.2<br>− 11.38 | 16 |
| ε Hya | 08 46 46.5<br>+ 06 25 07 | 3.38 | 77.0<br>− 11.53 | 17 |
| 1500BCE | | | | |
| ο Leo | 09 41 09.0<br>+ 09 53 32 | 3.52 | 95.7<br>− 4.05 | 7 |
| δ Cnc | 08 44 41.0<br>+ 18 09 15 | 3.94 | 80.2<br>− 0.31 | 10 |
| ε Leo | 09 45 51.0<br>+ 23 46 27 | 2.98 | 92.1<br>9.40 | 10 |
| ζ Hya | 08 55 23.6<br>+ 05 56 44 | 3.10 | 86.1<br>− 11.32 | 12 |
| ε Hya | 08 46 46.5<br>+ 06 25 07 | 3.38 | 83.9<br>− 11.47 | 13 |
| 1000BCE | | | | |
| δ Cnc | 08 44 41.0<br>+ 18 09 15 | 3.94 | 87.1<br>− 0.24 | 3 |
| ζ Hya | 08 55 23.6<br>+ 05 56 44 | 3.10 | 93.0<br>− 11.27 | 11 |
| ε Hya | 08 46 46.5<br>+ 06 25 07 | 3.38 | 90.7<br>− 11.41 | 11 |
| 500BCE | | | | |
| δ Cnc | 08 44 41.0<br>+ 18 09 15 | 3.94 | 94.0<br>− 0.19 | 4 |
| ζ Hya | 08 55 23.6<br>+ 05 56 44 | 3.10 | 99.9<br>− 11.21 | 15 |
| ε Hya | 08 46 46.5<br>+ 06 25 07 | 3.38 | 97.6<br>− 11.35 | 14 |
| α(2000) | Right ascension (h:m:s) | | | |
| δ(2000) | Declination (d:m:s) | | | |
| l | Ecliptic longitude (deg) | | | |
| b | Ecliptic latitude (deg) | | | |

sep Separation between ra $6^h$ and the star (deg)

is sufficiently dark for all bright stars to be visible. In this twilight, the position of the Sun in the sky is given by a faint glow on the horizon at the point of sunrise or sunset. A star close to this point can be considered to be in the same region of the sky as the Sun. The verses *RJ*.5-6 and *YJ*.6-7 also note that at the start of a *yuga* the asterism of *Śraviṣṭhā* is in the vicinity of the Sun at winter solstice. The Vedic sky-watchers would have determined the day of winter solstice by observing the apparent motion of the Sun; they were aware that at the solstices the 'Sun stands still' (*KB*.xix.3; Keith, 1920 and a number of other Vedic texts). However, the accuracy with which they would have determined the day when the 'Sun stands still' is not known.

In column six and seven of Table 1 are given the day after (+ ve) and the day before (− ve) the winter solstice when the respective star would have been seen to rise (column six) or set (column seven) helically. Consider the star δ Cap, around 2000BCE this star would have been first visible (under ideal seeing conditions) in the dawn astronomical twilight (the Sun 14° below the horizon) 22 days (column six) after winter solstice. At this first sighting the star would have been at about 4° above horizon (Schaefer, 1985). The essential point is that δ Cap would not have been visible before this day. On the days following this first sighting the star would have been seen at higher altitudes in the dawn astronomical twilight. Similarly, the star's last sighting in dusk astronomical twilight (the Sun 14° below the horizon) would have been 26 days (column seven) before winter solstice. Again the essential point is that the star would not have been visible after this day. On earlier days the star would have been sighted at higher altitudes in the dusk astronomical twilight. The presence of the Sun in the dawn and dusk astronomical twilight would have been manifested by a faint glow on the horizon at the location of sunrise or sunset. Around 1500BCE the first sighting at dawn would have been 30 days after winter solstice and the last sighting at dusk would have been 18 days before winter solstice. Similarly, the star β Aqr proposed by Abhyanker as the possible *yogatārā* of *nakṣatra Śraviṣṭhā* would have been visible at dawn 16 days after winter solstice and 19 days before winter solstice in the dusk twilight, this is at (or around) 2000BCE. Around 1500BCE this star would have been visible at dawn 23 days after winter solstice and 11 days before winter solstice in the dusk twilight. The *yogatārā* proposed by Narahari Achar (δ Cap) or that proposed by Abhyanker (β Aqr) would not have been visible to a Vedic sky-watcher within about ± 20 days of winter solstice. This is also true of all bright stars in Table 1, all possible *yogatārā* of *nakṣatra Śraviṣṭhā* by Narahari Achar's criteria. It is, of course, possible that the Vedic sky-watchers would have determined the stars in the vicinity of the Sun at winter solstice by observing the stars in the vicinity of the full moon at (or around) summer solstice 6 months earlier. However, would the Vedic ritualists have relied on observations made 6 months earlier or accepted an uncertainty of ± 20 days to start a *yuga* or start a new cycle of the annual sacrifice of *Gavām ayana*?

The identification of the star β Delphini as the *yogatārā* of the *nakṣatra Śraviṣṭhā* during the Vedic Period is questionable because of reasons given in the Introduction. However, this identification should not be dismissed lightly. At winter solstice, around 1500BCE this star (and the stars of the Delphinus constellation) is at the right ascension of $17.9^h$ and would also have been visible in the astronomical twilight at dawn and dusk at winter solstice, as has been shown by Gondhalekar (2013). This star will be at right ascension of $18^h \pm 30^m$ at winter solstice for few 100 years either side for 1500BCE. The star β Delphini is, of course, not within ± 10° of the ecliptic as prescribed by Narahari Achar. This prescription, however, is questionable; Narahari Achar does not provide any evidence and (to author's knowledge) the Vedic texts are silent on the rational for the choice of the *nakṣatras* or their *yogatārā*. In the Yajurvedic texts *nakṣatra Svāti* is called *Niṣṭhyā* (*MS* II.13.20; *KS* 39.13; *TB* 1.5; *TB* 3.14-5), that is, 'one kept far away' (I am grateful to an anonymous reviewer for bringing this to my notice). Although this is not evidence for *nakṣatras* at a distance from the path of the Moon, it does suggest that the choice of *nakṣatras* was more nuanced than Narahari Achar would have us believe.

## Conclusion

The proposed revision of the date of *Vedāṅga Jyotiṣa* to 1800BCE is not substantiated by detailed analysis. This analysis demonstrates that the star δ Cap and a number of bright stars including β Aqr satisfy the conditions prescribed by Narahari Achar that is, these stars are at right ascension around $18^h$ or they are in the same region of the sky as the Sun at winter solstice and they are within ± 10° of the ecliptic at all epochs between 2000BCE and 500BCE. Moreover, *nakṣatra Maghā* (identified by *yogatārā* α Leo) and *nakṣatra Āśleṣā* (identified by *yogatārā* ζ Hya) do not provide corroboration as the full Moon after winter solstice is in *nakṣatra Maghā* and the Sun is in *nakṣatra Āśleṣā* at all epochs between 2000BCE and 500BCE. There is an uncertainty of almost 1000 years in the proposed revised date. Moreover, the proposed *yogatārā* of *nakṣatra Śraviṣṭhā* δ Cap (and also the star β Aqr proposed by Abhyanker) will not be visible for ± 20 days around winter solstice that is, the Vedic sky-watchers would not have been able to visually verify the configuration of the Sun (and the Moon) and *nakṣatra Śraviṣṭhā* at the start of a *yuga* described in verses *RJ*.5-6 and *YJ*.6-7 of *Vedāṅga Jyotiṣa*.

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