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# The southern stars identified in Indian astronomical catalogues

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**Abstract.** In our effort to decipher the words and identify the stars as cited in the text *Sarvasiddhāntarāja* by Nityānanda of 15th century, we have found that most of the stars near the ecliptic belt are easily identifiable. The coordinate system used is *Dhruvaka* and *Vikṣepa*, which differ from the currently used ecliptic longitude–latitude and Right Ascension–declination coordinates. Most of the stars studied hitherto (Pai & Shylaja 2016, 2019; Shylaja & Pai Curr Sci 2018a, 2018b, 2019) were all in the northern hemisphere. It may be recalled that the name of the zodiacal sign (Pai & Shylaja 2016) for a group includes stars with all declinations – both north and south. For example, the group of *Meṣa* includes the stars of Andromeda. The only two southern stars that were mentioned in the group of Gemini are Sirius and Canopus. Here, we study the stars grouped under Libra and Scorpio, which includes bright stars in the southern hemisphere. The confusion about the *Dhruvaka* (east–west coordinates) is discussed.

**Keywords.** Stars identification in Indian astronomical texts—star names—*Dvijeśvara*—*Nṛpāda*—*Toraṇa*—*Aśvamukha*—southern stars listed from India.

## 1. Identification of the stars

As explained in our earlier work (Pai & Shylaja 2016, 2019; Shylaja & Pai 2018a, b, 2019a, b, c), the stars have been grouped under zodiacal constellations. The entire range of declination is included.

Here, we list the stars as derived from the star list of *Nityānanda* (Manuscript of *Siddhātarāja/Sarvasiddhāntarāja* by Nityānanda, Mss. no. 206 of A.1883-84, Bhandarkar Oriental Research Institute (BORI), Pune) (Pai & Shylaja 2020, submitted). The translations of the original texts are also provided so that one can appreciate the system of stating the coordinates: Instead of 2 degrees and 45 arc minutes, the text states 1/4th of a degree removed from 3 degrees. Similarly, 1/8th of a degree added to 3 implies 3/7/30 for *Svāti*.

The list begins with brightest stars Spica (*Citrā*) and Arcturus (*Svāti*) although it is known that they belong to Virgo. This very clearly indicates that the coordinates shown are not corrected for precession. This may also give the clue that the instrument they used was some form of an armillary sphere which was prepared for an earlier epoch. The text clearly states that the precession correction of 15° should be taken in to account. The coordinates of stars grouped under Libra are stated as follows:

'The coordinates of the star ***Citrā***, which shines with first order brightness along the southern direction, are one-fourth of a degree subtracted from three degrees (2 | 45) and two degrees, nine minutes (2 | 9). The star ***Svātī*** has the coordinates one-eighth of a degree added to three degrees (3 | 7 | 30) and thirty-one degrees and eighteen minutes (31 | 18). [This star] has first order brightness and is along the northern direction' (Pai & Shylaja 2020, submitted).

It should be noted that for Arcturus (*Svāti*), the coordinate *Dhruvaka* is provided to an accuracy of arc second. Both stars are having magnitude of 2. There is no ambiguity in the positions. The next statement is as follows:

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> 'One-fourth of a degree added to sixteen (*bhūpa*) degrees (16| 15) is one of the coordinates of the star named ***Dvijeśvara*** shines with second order along the south. The other coordinate is fifty-one degrees, fifty minutes (51 | 50). There is '**one star**' (***Nakṣatramekaṃ***) which is situated along the north (*vāg*) always with second order brightness has the coordinates half a degree along with seventeen degrees (17 | 30) and one-fourth of a degree added to fifty-five degrees (55 | 15)' (Pai & Shylaja 2020, submitted).

Now, the coordinates of two stars in the extreme declinations are given. The numeral notation for 16 is expressed in *Bhūtasaṅkhyā* system as *bhūpa*, which means 'the king'. In all future citations the *Bhūtasaṅkhyā* cordinates have been provided in parentheses. Both stars are having magnitude of 2. One star is called *Dvijeśvara* while the other has no name, making the identification difficult. The coordinates of *Dvijeśvara* takes us to the Southern Cross. The conversion of *Vikṣepa* to declination as 57° 50′ S can be matched either with α (−59°) or γ Crucis (−54°). The unnamed star in the north has a difference in the *Dhruvaka* of about 1° with *Dvijeśvara*. This fact also cannot be used to fix either of the stars since there is uncertainty in fixing the former. The northern star with declination 48°N can be η UMa (52) or β Bootis (46). The role of atmospheric extinction is very obvious since the observer is at a latitude of about 25°N.

A search in the catalogue of astrolabes by Sarma (2018) did not show these southern stars since most of the astrolabe manufacturers were located in the regions beyond about 25°N. Therefore, it is unlikely that these stars could find a place on the astrolabe dial. Nityānanda seems to have included them because they are fairly bright and as a keen observer he had seen them at meridian transit. The name *Dvijeśvara* is an adjective for any great sage; therefore, the particular sage he is referring to is not immediately clear. In the mythological themes only sage *Agastya* (Canopus is named after him) is associated with the southern hemisphere. Therefore, the identity of the sage with this star can be established if any other reference to this star is available.

The next verse concerns three more stars of Libra:

> 'The star which has the coordinate one-sixth of a degree added to twenty-one degrees (21 | 10) is the ***Mātṛcakra***. This has second order brightness and is along the north with the coordinate half a degree along with forty-five degrees (45 | 30). '**[One] star**' (*Ṛkṣam*) has coordinates twenty-one degrees, thirty-seven minutes (21 | 37) and fifty-one degrees, forty minutes (51 | 40) towards south and has second order brightness. Twenty-four (*siddha*) degrees, twenty-eight (*piṇḍa*) minutes (24 | 28) is the coordinate of the star ***Tulaikasikkā*** which is directed towards the south with third order brightness. The other coordinates one-fourth of a degree subtracted from one degree (0 | 45)' (Pai & Shylaja 2020, submitted).

First two of these stars have a magnitude of 2, while third one has a magnitude of 3. *Mātṛcakra* is a new name; it is not a translation of the Persian or Arabic name. The declination (+37°) can be matched with δ Bootis (35°), although the Right Ascension if off by almost 15°. As mentioned earlier, the precession correction of 15° is not applicable uniformly to all the stars. Therefore, declination can be the decisive factor.

Malayendu's catalogue (Raikwa 1936) of 13th century lists a star called *Mātṛmaṇḍala*. Its declination is derived from the maximum altitude considerations. It has a 'Pharasi' name Fakka, which corresponds to α Corona Boreolis (Alphecca). In one of the astrolabes, Corona Boreolis (Arabic name al-Fakka) is identified as *Viśākhā - Mātṛmaṇḍala* (Sarma 2018, p 3203). The source for this identification is not known. *Viśākhā* is listed as another star whose coordinates are available in the next sentence of the catalogue text. It has a negative declination and cannot be confused with *Matṛmaṇḍala* or *Mātṛcakra*.

Figure 1 shows the locations of *Matṛmaṇḍala* and *Mātṛcakra*. It may be seen that neither agrees with Alphecca, (α Corona Boreolis). It appears more δ appropriate to call *Matṛmaṇḍala* as β Bootes and *Mātṛcakra* as δ Bootes. The words *Maṇḍala* and *Cakra* refer to something circular. Therefore, the intended star group may be Corona Boreolis. We attempted the reversed calculation for β Bootes, which yields as *Dhruvaka* as 194.83 (the recorded value is 197.41). This means the precession correction is not 15°, but lesser.

It may be seen that Corona Boreolis has five stars arranged like a stringed decorative jewellery for a crown and hence the name corona. Interestingly all of these stars are binary systems, the variation in brightness has different periodicities (SIMBAD-AD: https://simbad.u-strasbg.fr/simbad/). The brightest of them, α, has period of 16–17 days and the decrease in magnitude because of eclipses is about 0.1. This is barely recognisable to the naked eye. Other stars in the crown have different periodicities. However, none of them can surpass α in brightness. It is to be investigated if any of them did brighten up 1000 years ago to justify their entry in to the catalogue here.

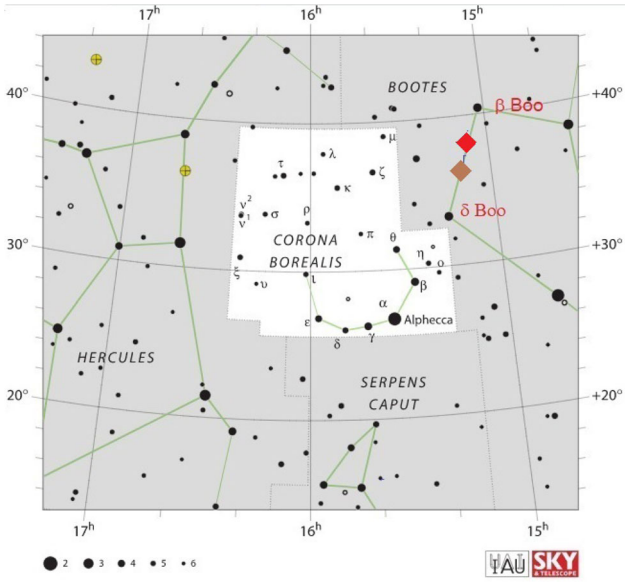


**Figure 1.** The positions of the stars called *Mātṛcakra* by Nityānanda (brown diamond) and *Matṛmaṇḍala* (red diamond) by Malayendu. It may be seen that the identification is rendered difficult because of the uncertainty in the *Dhruvaka* coordinate, which affects the calculation of the declination (adapted from the figure in Wikipedia). This file is licensed under the Creative Commons Attribution 3.0 Unported license.

The next statement is about a southern star with no specific name. For the *Dhruvaka* and *Vikṣepa* value, its declination works out to be −55/20. Its magnitude is 2. This agrees with the identification of β Centauri. But the precession correction is not correct. Therefore, we have to consider some other source of error.

The next two stars do not have specific names. We notice that the faint 3rd magnitude star is called the first star of Libra. In the next statement we see the phrase 'the other star of Libra' without any specific name. They can be identified with α and β Librae. Both stars are quite faint of 3rd and 4th magnitude. It is quite intriguing that the individual names are not written down.

> 'The star ***Tulānyasikkā*** has the coordinates twenty-eight (*piṇḍa*) degrees, thirty-three (*trirāma*) minutes (28 | 33) and one fourth of a degree (*vipāda*) subtracted from nine (*kheṭa*) degrees (8 | 45). It shines along the north with third order brightness. The star ***Viśākhā*** is situated along the north, at the position from where eight minutes are remaining in the *Tulā*[*rāśî*], with the brightness of fourth order. [That is, the longitude is twenty nine degrees, fifty-two minutes (29 | 52)]. The second coordinate is one-fourth of a degree (*vyaṅghri*) subtracted from two (*yugma*) degrees (1 | 45). These are the only nine stars (*dhiṣṇya*) which are situated in *Tulā*[*rāśî*] in the sky which have been accepted by the people with knowledge of astronomy' (Pai & Shylaja 2020, submitted).

*Viśākhā* is at the edge of the boundary of *Tulā*. Its declination is −12°53′; it can be γ Librae or α Librae because of the uncertainty in precession correction. The sentence concludes with the declaration of the 6 stars of Libra.

The next sentence is about the stars of Scorpio:

> 'The star ***Anurādhā*** shines with third order brightness along the southern direction with the coordinates eleven degrees, thirty three minutes (11 | 33) and two degrees, three minutes (2 | 3) respectively. One-third of a degree subtracted from fifteen (*tithi*) degrees (14 | 40) is the one of the coordinates of the star ***Nṛpāda*** which shines with first order brightness along the southern direction with the latitude forty-one degrees along with one-sixth of a degree (41 | 10)' (Pai & Shylaja 2020, submitted).

There is no ambiguity in the identification of δ Scorpii with *Anurādhā* (Pai & Shylaja 2016). The southern star *Nṛpāda* is of magnitude 1 and therefore very bright. It matches with α Centauri. Again, here the *Dhruvaka* value does not match. Since there is no other bright star in the south we have to consider some source of error which is affecting the coordinates of the southern stars. This name *Nṛpāda* appears to have been derived from the Arab source since it refers to the foot of 'a man'.

> 'One-eighth of a degree subtracted from nineteen degrees (*govidhu*) (18 | 52 | 30) is the *dhruvaka* of the star ***Jyeṣṭhā*** whose order of brightness is two and the *śara* is one-third of a degree subtracted from five degrees (4 | 40) along the southern direction. Along the north, with the *dhruvaka* of twenty degrees (20 | 0), with fourth order (*vedamitaṃ*) brightness, there is a star known as ***Yugma*** is situated whose *śara* is seventy-five (*śarādri*) and a half degrees (75 | 30)' (Pai & Shylaja 2020, submitted).

There is no ambiguity in the identification of α Scorpii with *Jyeṣṭhā* (Pai & Shylaja 2016). The next set of values is for a double star at a declination of + 57/30. We have to look for pairs of stars in this region. The pair with β Ursa Minor is too far to the north and γ and β Draco are quite off in right ascension. The stars are arranged in the order of increasing of *Dhruvaka*. *Anurādhā* (δ Scorpii) has a *Dhruvaka* value of 221° and *Yugma* has 230°. Therefore, we have to reject γ and δ Draco. The location approximately agrees with ι Draconis. The option for the

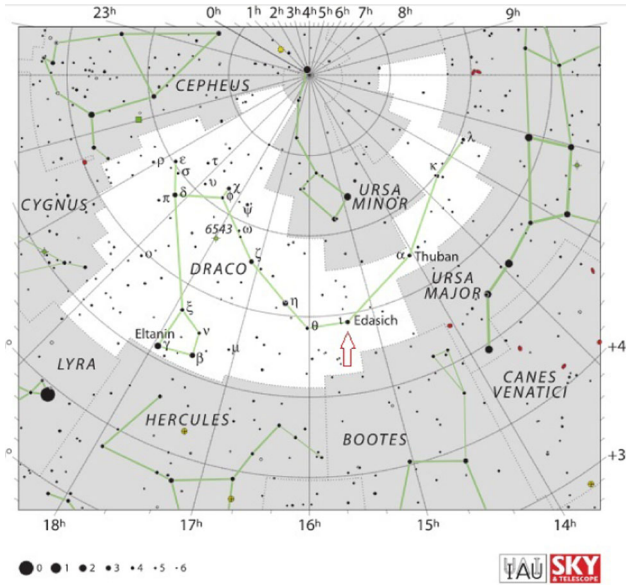


**Figure 2.** The location of the double stars called *Yugma* is indicated by the arrow. It agrees with Iota Draconis. However, the companion cannot be identified. The bright star is η Draconis is not near enough to be declared as a pair (adapted from the figure in Wikipedia). This file is licensed under the Creative Commons Attribution 3.0 Unported license.

second star of the pair is η Draco. This is clear from Figure 2.

> 'The star ***Sarpaśīrṣa*** which is situated always along the north with three degree of brightness has the coordinates twenty-four and a half degrees (24 | 30), and thirty-seven degrees (37 | 0) respectively. These are the only five stars known to be present in the *rāśî* known by the name *Vṛśćika'* (Pai & Shylaja 2020, submitted).

The star *Sarpaśīrṣa* represents the head of a serpent (Figure 3). The coordinates approximately match with the location of the hood of the serpent. Again, there is no clarity on which of the stars is to be identified with it. We can understand that the name has been borrowed from the original Arab source for the catalogue of the astrolabe.

Thus, there are only five stars declared for Scorpio.

There is a star named *Aśvamukha* listed by Padmanābha in *Yantrakiraṇāvali* (Ohashi 1997). Its coordinates (240 and 56/30N) place it in Hercules. There is no information on the brightness. Another star identified by Padmanābha is called *Toraṇa* (225 and 25N). This can be identified with α Serpentis. These are marked in Figure 3 as blue diamonds. There is no ambiguity in these cases. However, the names do not appear to be translations from Arabic sources. This is the first reference to these stars. *Aśvamukha* means the head of a horse and *Toraṇa* means decorative archway at the main entrances of palaces/temples. Therefore, the origin of the name needs to be explored from other sources. We have also compiled all these stars along with their coordinates in Table 1.

## 2. Discussion

The coordinate system poses a serious problem in identification, as we have seen earlier. The bright stars serve as references so that the values can be interpolated for fainter stars. However, there is another source of error which shows up in the grouping itself. This becomes more pronounced for this group of Libra and Scorpio.

We shall see now that the errors and confusion are the significant for the stars at extreme declinations (both northern and southern).

As explained in Paper I, we converted all the coordinates to Right Ascension and declination. This will not match the position because of the precession correction which is specified as 15° in the beginning of the text. To determine the exact value, we used the bright stars *Citrā* (Spica) and *Svāti* (Arcturus). The solution is easier said than done. It appears that there is a time difference between the records of positional observations since the correction of precession will agree either for Spica or for Arcturus. This is explained in Figure 4, which depicts the exact problem.

Since the epoch of 1428CE requires 15° as the *Ayanāṃśa* correction, we applied the same for the values of the *Dhruvaka* and calculated the corresponding declination. The figure shows the positions as converted by Nityānanda's catalogue as blue diamonds. The corresponding positions for that epoch as derived from Stellarium are represented by brown squares.

We notice that the agreement is within the errors of the instrument. The mismatch of RA amounts to about few minutes for almost all stars except the southern ones, α and β Centauri as well as α Crucis. These are shifted off by almost about 2 h, as indicated by the horizontal lines in the figure. Thus, there is a systematic error for the three southern stars.

This takes us to an interesting question as to why an additional correction became necessary for only the southern stars. Although the answer is not very straightforward, we may analyse the method of

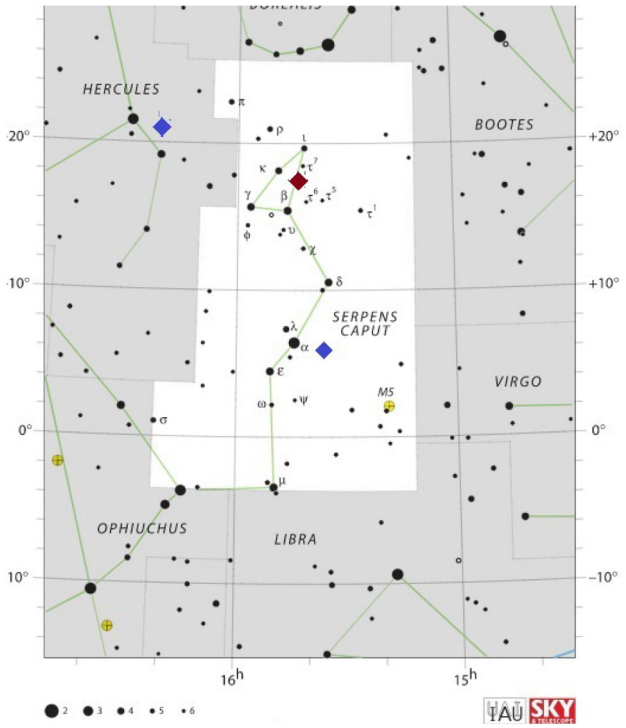


**Figure 3.** The star marked with brown diamond in Serpens Caput is *Sarpaśīrṣa*, meaning the head of the serpent. There is no clarity on which of the stars is to be identified with it. Two stars marked with blue diamonds are from *Yantrakiraṇāvali* by Padmanābha; the names are *Toraṇa* and *Aśvamukha* (adapted from the figure in Wikipedia). This file is licensed under the Creative Commons Attribution 3.0 Unported license.

writing the coordinates. They are written in bins of the 12 zodiacal constellations. For example, the *Dhruvaka* of *Aśvinī* (α Ari) is written as 10. That of *Punarvasu* (α Gem) also is written as 10. It is expected that we add the necessary angle corresponding to Gemini. Thus, the reading for *Punarvasu* will be 60 + 10 = 70. In this method if the star is assigned to a wrong group, the difference will be 30°, which is 2 h in RA. In this study, we notice that the three southern stars ought to have been grouped into Leo itself.

All the three southern stars (declination of about 60° S) are seen quite low, with maximum altitude of about 5° from the latitudes north of 25°. The fact that Nityānanda included them in the list itself is a testimony to his observational efforts. Other lists, for example, by Malayendu, do not include them at all. At such low altitudes, the atmospheric refraction can contribute to the errors significantly. Almost all the astrolabes (prepared from northern latitudes) of the catalogue of Sarma (2018) do not have these stars listed for the rete (the rotating dial with star names inscribed).

In the context of the seven stars of Ursa Major (*Saptarṣi Maṇḍala*) we had noticed similar errors (Shylaja & Pai 2019b). Since these are well-established bright stars, the identification was easy. In a crowded star fields, any unidentified star or new star will be easily lost. We encountered difficulty in respect of stars whose coordinates are not written

**Table 1.** Compilation of stars of Libra and Scorpio.

| Dhruvaka (Deg ⁞ Mins) | Vikshepa (Deg ⁞ Mins) | Magnitude | Name | Identification |
|---|---|---|---|---|
| 182 ⁞ 45 | 2 ⁞ 9 S | 1 | *Citrā* | Spica / α Vir |
| 183 ⁞ 7.5 | 31 ⁞ 18 N | 1 | *Svāti* | Arcturus / α Boo |
| 196 ⁞ 15 | 51⁞50 S | 2 | *Dvijeśvara* | γ Cru |
| 197 ⁞ 30 | 55 ⁞ 15 N | 2 | no name | β Boo |
| 201 ⁞ 10 | 45 ⁞ 30 N | 2 | *Mātṛcakra* | α Cr B |
| 201 ⁞ 37 | 51 ⁞ 40 S | 2 | no name | β Cen |
| 204 ⁞ 28 | 0 ⁞ 45 S | 3 | *Tulaikasikkā* | α Lib |
| 208 ⁞ 33 | 8 ⁞ 45S | 3 | *Tulānyasikkā* | β Lib |
| 209 ⁞ 52 | 1 ⁞ 45 N | 4 | *Viśākhā* | α Lib / μ Lib ?? |
| 221 ⁞ 33 | 2 ⁞ 3 S | 3 | *Anurādhā* | d Sco |
| 224 ⁞ 40 | 41 ⁞ 10 S | 1 | *Nṛpāda* | α Cen |
| 230 ⁞ 00 | 75 ⁞ 30 N | 4 | *Yugma* | γ & β Dra |
| 228 ⁞ 52.5 | 4 ⁞ 40 S | 1 | *Jyeṣṭhā* | α Sco |
| 234 ⁞ 30 | 37 ⁞ 00 N | 3 | *Sarpaśīrṣa* | α Ser |
| 240 | 56 ⁞ 30 | | *Aśvamukha** | α Her |
| 225 | 25 N | | *Toraṇa** | α Ser |

*Stars from the list of Padmanābha.

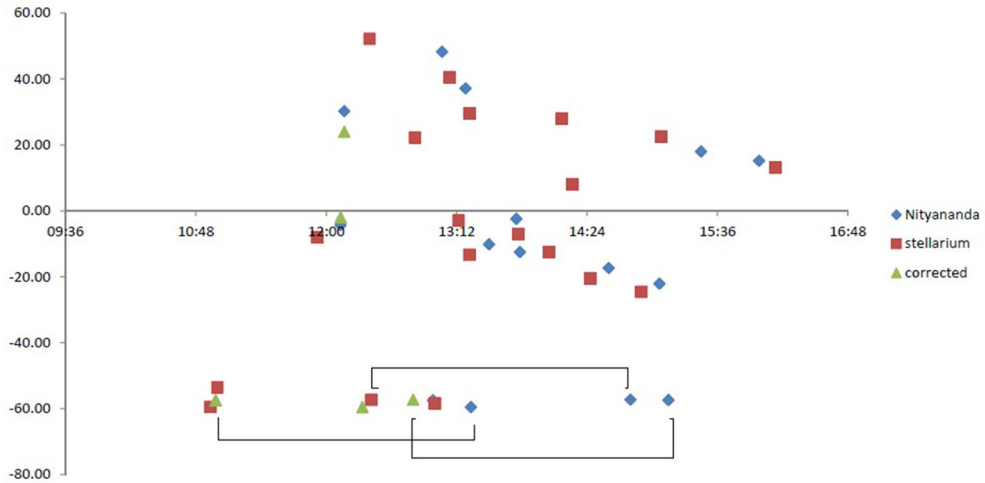


**Figure 4.** The coordinates are plotted on the right ascension – declination axes. The blue diamonds correspond to the locations as specified by the text. The brown squares are from Stellarium for the epoch of 1428CE. The three southern stars needed an extra shift as indicated by the horizontal lines. The revised positions are indicated by green triangles.

down specifically but simply stated relative to Spica (Shylaja & Pai 2019c); these stars called *Āpa* and *Apāṃvatsa,* perhaps are two variable stars.

It may also be seen that the names of constellations have not been translated in all cases. *Nṛpāda* refers to 'the foot of a human'. Similarly, the *Tulaikasikkā* and *Tulānyasikkā* translate as one star of the Libra and the other star of the Libra.

Since Nityānanda has specified that he lived at a latitude of 26°N, we now discuss the visibility criterion specific for his epoch. The southern stars discussed here are α Cen, β Cen and γ Cru. Among these, α Cen is not visible from Delhi. β Cen is barely visible, just 3° above the horizon for about half an hour at meridian transit. γ Cru is visible for a 2 to 3 h from February to June, very low in the southern horizon with a maximum altitude of just about 6°. Thus, it is a mystery as to how Nityānanda was able to include these in the list with the estimates of the magnitude. We can consider three possibilities:

a. He obtained the coordinates of these stars from some other source.
b. He had observed these stars from a latitude south of Delhi and incorporated them.
c. He simply copied them from a catalogue and did not carry out observations.

Option (a) is a little unrealistic because any source would have to come from a southern latitude. Since all astrolabes were made at 28°N or further to the north, it is unlikely that such a source was available. In the compilation of astrolabes (Sarma 2018), we find that even Sirius and Canopus do not find a place in all astrolabes. We also do not consider option (c) since the identifications appear to have been judged from observations, especially the brightness estimates as magnitudes.

Since we do not have any idea of his life and education, we can only speculate his familiarity with southern stars. A visit to a place like Ujjain would show all the three stars albeit quite low (7° to 11°) in the southern horizon for about 2 h from February to June. This familiarity and inability to verify can partly explain the confusion that has shown up in assigning them to the appropriate Right Ascension group. γ Cru has been given the name *Dvijeśvara,* which appears to be an original Sanskrit name already in use. For the stars of Centaurus, one has a name *Nṛpāda* (the foot of a man) and the other has no name – simply mentioned as one star. *Nṛpāda* can be inferred to have been derived from the name Centaurus.

## 3. Conclusions

In our efforts to prepare a list of stars as recorded in the Sanskrit texts, we have presented the results in the RA band covered by Libra and Scorpio. It clearly shows the difficulties in fixing the positions. This may be due to differences in the precession corrections or some instrumental effects. Some of the names like *Nṛpāda* appear to be translations from Arab sources. *Dvijeśvara, Matṛmaṇḍala* and *Yugma* are new names and not translations. We have also included the new names *Aśvamukha* and *Toraṇa* from *Yantrakiraṇāvali* of Padmanābha of the 15th century.

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