Observational records of stars in Indian astronomical texts – IV (Cancer and Leo)

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In an effort to search observational records of stars in Indian Astronomical texts, we have compiled all bright stars in various texts from Sūryasiddhānta to Siddhāntadarpaṇa by Candraśekhara Sāmanta of the 19th century. We have used the well-known 27 nakṣatras on the ecliptic for fixing the coordinates. This has resulted in unambiguous identification of faint stars. A scale similar to the magnitude scale of brightness in one of the texts has further helped in identifying the faint stars. Here we discuss the stars grouped under Cancer and Leo. It is interesting that Puṣya is described as one with the appearance of a cloud. Two names hitherto unknown and a mention of the pole of the ecliptic are also reported.

The coordinate system

As explained by Venketeswara Pai and Shylaja[1], the coordinates of stars in all Indian astronomical texts are expressed in *Dhruvaka* and *Vikṣepa*, whose exact equivalent terms are not found in texts on modern spherical astronomy. All the sets of coordinates are inter-related by trigonometric relations to transform one set of coordinates to another. Similarly, *Dhruvaka* and *Vikṣepa* also can be converted to right ascension (RA) and declination of conversion of coordinates. One of the earliest attempts was by Burgess[2]; subsequently, others have come up with alternate formulae. While comparing different methods, Abhyankar[3] discusses the advantages of the *Dhruvaka–Vikṣepa* system. The coordinates have been described in the verses or prose, or encoded in the form of phrases in various texts.

Our earlier studies[1,4] have shown that the coordinates are generally provided for a different epoch. The precession corrections have to be added as and when required. The comparison becomes easy upon conversion of the coordinates using trigonometric relations. This is essential to compare the coordinates. The ambiguity in the identification of stars arises because the east–west coordinates are influenced by the shift in the reference point, the First Point of Aries, owing to precession.

We examined the identifications of 27 stars named *Yogatāras* (junction stars) with those that are conventionally known to us now[1]. These 27 stars are listed almost in every book on astronomy, from Colebrook[5] for the stars from the *Sūryasiddhānta*[2] to *Siddhāntadarpaṇa* of Candraśekhara Sāmanta[6] (the last traditional astronomer of the 20th century). Mahendra Sūri who translated the manual *Yantrarāja* using the astrolabe into Sanskrit for the first time in 13th century[7]. We have examined the works of Malayendu (commentary on *Yantrarāja*, 15th century)[8], Nityānanda (who wrote *Siddhāntharāja*, 15th century)[9], Padmanābha (author of *Yantrakiraṇāvali*, 16th century)[10], Putumana Somayājī (*Karaṇapaddhati*, between 16th and 18th century[11].

The texts by Nityānanda, Padmanābha and Malayendu provide direct measurements. Malayendu lists another quantity, viz. *paramonnatāṃśa*, which is a measured parameter. As explained in our earlier study[1], this is the maximum altitude from which the declination can be directly derived. Since the declination accurate to seconds also has been listed separately, we can infer that it is derived based on calculations. It differs from the declination derived directly from maximum altitude, though only slightly. It can be either treated as an instrumental error, or a correction deliberately applied (maybe for refraction). Noticing that all the values of *Dhruvakas* (for 32 stars) end with 33′52″, we can infer that they are calculated and/or corrected. The exact method of application of corrections is yet to be extracted from texts devoted to observational records. Thus the measured quantities are only *vikṣepa* and *paramonnatāṃśa* (given values accurate to minutes).

We have converted the given coordinates of all stars to RA and declination, as explained in detail in the earlier study[1]. Nityānanda provides the brightness as a scale called *pramāṇa*, which is equivalent of the magnitude scale used today. The first (*prathamapramāṇa* or *ādyamāna*) is the brightest; the second brightest is *dvimiti*, the third is *trimiti*; and fourth is *caturtha-pramāṇa*. These scales are specifically described in the middle of the text as explained later after the description of stars of Leo.

The stars are arranged in order of increasing *Dhruvakas* and are grouped according to their *Dhruvakas*. Thus group Aries contains stars within 0°–30° with all possible values of *Vikṣepa* (north–south). We have earlier described over the stars of Aries and Taurus[4], as well as the stars of Gemini[12]. Here we cover all stars under Cancer and Leo.

We have observed that the names provided in the list are not all necessarily of Indian origin; some are of Arabic origin. Malayendu's list gives the original names as *pāraśī-nāma*, meaning the 'name from Persia'. The Sanskrit names are literal translations in many cases.

The seven stars of the *Saptarṣi* are divided into different groups according to their longitudes. The names are not specified; but stated as the first *muni*, the next *muni*, the one after that ... and so on. We have included the names as and when they are available. In the recent catalogue of astrolabes by Sarma[13], many new names have appeared. We have included these in our tabulation.

The stars of cancer

It is well known that Castor and Pollux belong to the constellation of Gemini; however, here they are included under Cancer. This is due to the fact that precession corrections are not considered in the tabulated version. The commentary bv Malavendu refers to Castor as *Prathama Bālaśirṣa*/प्रथमबालशीर्षम्, meaning the head of the first boy (between the two in Gemini). All texts list coordinates of not only solar system objects, but also stars in the *Nirayaṇa* system. Due to the

same reason two stars of Leo have moved into the group under Virgo, as we shall see later.

Cancer is a constellation devoid of bright stars. A small triangle with the star cluster Praesepe (popularly called Beehive) is generally considered as a group for marking *Puṣya*/पुष्यः. The coordinates, in our previous study[1], point to this cluster and the earlier identifications are with the small triangle or with δ Cnc (delta Cancri). However, the text by Nityānanda refers to it as 'one which looks like a cloud', aptly describing the real situation. It looks like a nebula and is included in the list of Messier for this reason. Thus it reiterates that fact that the list has been prepared by Nityānanda after taking actual measurements.

Although *Āśleṣā*/आश्लेषा is also a very faint star, there is no ambiguity in its identification with α Cnc (Alpha Cancri, Acubens).

The bright star ζ Pup (Zeta Puppis) gets included in this list because its *Dhruvaka* is in the boundary defined by Cancer. It is called *Naukā*/नौका, and therefore can be considered a translation[14]. The word 'Puppis' does not correspond to dog litter, but poop deck or stern of a ship. Therefore, this supports the observation that many star names have been derived from the West, as mentioned earlier[1]. Interestingly, it has no bearing with the Arabic name *Suhail Hadar*, but sounds similar to the Greek name Naos. It can also mean that the name *Naukā*/नौका was passed onto the Greeks, if we assume that this is of Indian origin. Since the star is visible from South India very prominently, its association with the sea (by navigators) is quite understandable.

A pair of stars, simply called *yugmaka*/युग्मकम्, is also included in this group, though it is in the constellation of Ursa Major. There are two more such pairs. All the three belong to Ursa Major and are identified as the footprints of Trivikrama/त्रिविक्रमः.

The stars of Leo

A star named *Ārdra-Lubdhaka*/आर्द्रालुब्धक appears in many astrolabes. It gives rise to doubts on the identity as α CMa (Sirius) itself, or α Ori (Betelguese) in may astrolabes. It is also listed by Malayendu. The coordinates point to β CMa (Beta Canis Majoris). Likewise, we notice that the name *Siṃhahṛdaya*/सिंहहृदयम् (heart of the lion) has been used for α Leo (Regulus) while the general name is *Maghā*/माघा. Many astrolabes have got this name engraved for *Maghā*/माघा. However, identification has not been provided in the catalogue, but left with a question mark. At least in one case it has been wrongly identified with ζ UMa (Mizar or Zeta Ursa Majoris). This is quite understandable considering the large error that creeps in while engraving the tips of the pointers.

In many astrolabes the star α Hya (Alpha Hydrae, Alphard) has been marked with the name *Mahāpuruṣa*/महापुरुषः. Similarly, we find the star α Crt (Alpha Crateris, Alkes) marked in some of the astrolabes. Since the precise coordinates are not listed, we cannot include them in the table. The star β Leo (Beta Leonis, Denebola) has another name *Āryamān*/आर्यमान् in one of the astrolabes.

The bright star γ Vel (Gamma Velorum) has been named *Bhujaṅga*/भुजङ्गः by Nityānanda. A corresponding entry is not seen in any other astrolabe. This appears to be an original Indian name since it does not correspond to any translation. The origin of the name is not known.

The last statement of the description of the stars of Leo pertains to the magnitude scale which is discussed in our earlier study[1], followed by the procedure for correction of coordinates for the given epoch. It states 'To start with the *Dhruvāṃśas* have to be (corrected) brought the true *rāśi*s. Afterwards (and not the other way) *śaras* are decided as to the north or south as prescribed in the traditional texts by experts and scholars.'

We have followed the same procedure in the conversion of coordinates for the different epochs. Here it should be noted that *śara* and *Vikṣepa* are different. The precession correction is added to *Dhruvaka* and then the corresponding *śaras* are determined from the measured *śaras* values.

Discussion

Table 1 shows all the stars listed under Cancer and Leo. The first entry *punarvasu*/पुनर्वसुः appears in Paper III (ref. 12), also as explained earlier. The star Procyon is named *Lubdhaka-bandhu*/लुब्धकबन्धुः, which clearly depicts its position next to *Lubdhaka*/लुब्धक (Sirius). It is also called *Vyādhānuja*/व्याधानुजः. There are three pairs of stars identified as *Yugmaka*/युग्मकम्. The reference to *Trivikrama*/त्रिविक्रमः has been discussed in the context of a hitherto unknown constellation named *Trivikrama*/त्रिविक्रमः.

Puṣya/पुष्यः is usually identified as δ Cnc (delta Cancri). However, in the description Nityānanda clearly mentions that it looks like a cloud. This refers to the star cluster visible to naked-eye Beehive or Praesepe, which becomes visible only if the sky is free of light pollution and also moonlight. Its magnitude is not specified. Thus this becomes the first ever observational record of the star cluster in an Indian text. From Figure 1 (position indicated by plus mark), it is clearly seen that any of the three stars can be matched.

The ambiguity in respect of *Āśleṣā*/आश्लेषा has already been discussed[1]. It has only the *Dhruvaka* listed and not the *Vikṣepa*. The largest and most extensively used astrolabes, numbered D090 in the catalogue[13], provides quite accurate values of *Dhruvakas* and *vikṣepas*. It is in the collection of instruments by the Rajput King Jai Singh at Jaipur Observatory, Rajasthan. It has the *vikṣepa* as well as the declinations engraved for all the stars. The *vikṣepa* for *Āśleṣā*/आश्लेषा is zero. This may be the reason that it has not been specified by Nityānanda.

The two stars of *Saptarṣi* are simply referred to as the first and the next. The engraving for the star α Ursa Majoris is read out as *Ṛdhpada*/ऋध्पद in the astrolabe numbered E003 (ref. 12). (The prefix E corresponds to astrolabes with both Persian and Sanskrit names engraved on the rete.) Since there seemed to have been some difficulty in reading it, a correction as *Ṛkṣapṛṣṭha*/ऋक्षपृष्ठः (meaning back of the bear) has been suggested. Similarly, the name of α Crateris is read as *Jāmapakṣī* and the suggested correction is *Jāma* (?) of a bird. The question mark refers to the uncertainty in the meaning associated with the word *Jāma* for a bird. However, presuming that this is a translated name, for the word Crater (meaning a bowl) *Jāmapātra* (vessel for measuring time, *Jāma* = *Yāma* = unit of time) may be a suitable alternative. This new name can be included in the table after the coordinates are read out from the rete.

The two entries corresponding to *Dhruvākṣa*/ध्रुवाक्षः and *Pūrva-Dhruvākṣa*/पूर्वध्रुवाक्षः (meaning pole of ecliptic) correspond to stars χ Draconis and δ Draconis respectively. A corresponding

Table 1. Identification of stars from the catalogue of Nityānanda and comparison with other texts

Star	Text	*Dhruvaka*	*Vikṣepa*	Magnitude	Maximum altitude	Identification/remarks
Punarvasu/पुनर्वसुः	SR SS	92 | 30	6 | 30 N	2		Castor (this is grouped under Mithuna in Paper III)[12]
Prathama Bālashirsha/ प्रथमबालशीर्षम्	SD CYR					
Lubdhakabandhu/लुब्धकबन्धुः *Vyadhānuja*/व्याधानुजः	SR YK YR SD	95	16 S	1	67/36	Procyon α CMi
Yugmaka I/युग्मकम् I	SR	102 | 20	29 N	3		ι UMa and κ UMa
Puṣya/पुष्यः	SR CYR SD SS	106 | 20	1 N	Magnitude is not given*		Star cluster Praesepe δ Cancri
Āśleṣā/आश्लेषा	SR CYR SD SS	112 | 30	6 | 55 S	3		α Cancri ε Hydrae
Dhruvākṣa/ध्रुवाक्षः	SR	112	73 N	2		χ Draconis:
Munīndra/मुनीन्द्रः *Ūrdhva-paścimaga*/ ऊर्ध्वपश्चिमगः *Ṛkṣapṛṣṭha*/ऋक्षपृष्ठः	SR YK AS	114	49 | 24 N	2		α Ursa Major
Naukā/नौका	SR	116 | 45	58 | 36 S	2		ζ Puppis
Anyomuni/अन्योमुनिः *Adhaḥ-paścimaga*/अधःपश्चिमगः	SR YK	118 | 15	45 N	3		β Ursa Majoris
Yugma/युग्मम्	SR	119 | 45	29 N	3		λ UMa and μ UMa
Pūrva-Dhruvākṣa/पूर्वध्रुवाक्षः	SR	120 |30	75 N	4		δ Draconis: location of the pole of the ecliptic is to its east
Bhujaṅga/भुजङ्गः	SR	125 | 50	64 | 15 S	2		γ Velorum
Siṃhāsaka/सिंहासकः	SR	128 | 33	9 N	2		γ Leo
Maghā/माघा *Siṃhahṛdaya*/सिंहहृदयम्	SR CYR SD SS AS	128 | 50	0 | 10 N	1		Regulus: α Leo
Puratomunīndra/पुरतोमुनीन्द्रः	SR	129 | 7	47 N	3		γ Ursa Major
Tatpuratomunīndra/ तत्पुरतोमुनीन्द्रः *Prāgmuni*/प्राग्मुनिः	SR YK	130	51 | 30 N	3		δ Ursa Major
Yugmaka II/युग्मकम् II	SR	137 | 0	25 N	3		ν UMa and ξ UMa
Vasiṣṭha/वसिष्ठः	SR	137 | 10	54 N	2		ζ Ursa Major
Siṃhasyapṛṣṭha/सिंहस्यपृष्ठम्	SR	140	14 S	2		θ Leo
Purva-Phālgunī/पूर्वफाल्गुनी	SR	142 | 15	9 | 30 N	3		δ Leo Zosma
Muni/मुनिः	SR	144 | 40	56 | 15 N	2		η Ursa Major

*It is told that the star shines like a cloud star cluster; *megha-pratimo vibhāti*.

SR, *Siddhāntarāja*/*Sarvasiddhāntarāj* of Nityānanda; YR, *Yantrarāja* by Mahendasūri (identifications by Pingree); SS, *Sūryasiddhānta*; CYR, Commentary on YR by Malayendu; YK, *Yantrakiraṇāvali* by Padmanābha; SD, *Siddhāntadarpaṇa* by Sāmanta Candraśekhara; AS, Catalogue of astrolabes.

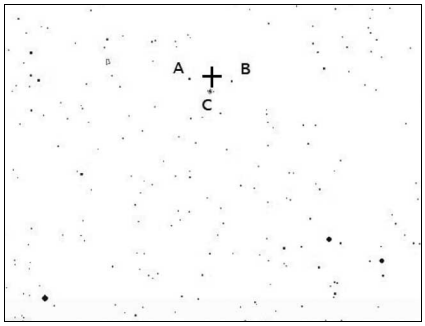

Figure 1. Field of the small triangle ABC of stars representing *Puṣya*/पुष्यः, whose position according to the coordinates is indicated by the plus symbol. A is delta Cancri and C is the star cluster Praesepe.

entry is not available in any other reference. It is mentioned that the first star is situated to the west of the *Dhruvākṣa*/ध्रुवाक्षः. *Pūrva-Dhruvākṣa*/पूर्वध्रुवाक्षः may indicate that this was the earlier *Dhruvākṣa*/ध्रुवाक्षः, or the present pole is to the east of this star. Either way, the two stars serve as references for the pole of the ecliptic. The separation in *Dhruvaka* between the stars is 8°.

The nutation causes a small change in the pole of the ecliptic as well. The shifts of the longitude of the ecliptic Π_A and the annual rate of rotation π_A, owing to precession, have been determined[15]. The value of π_A is only about 0°.0001305 per year and Π_A is about 174° for J2000 and the precession motion is given by[16]

$$\sin \pi_A \sin \Pi_A = 4''.199094T + 0''.193987T^2 - 0''.00022466T^3,$$

$$\sin \pi_A \cos \Pi_A = -46''.811015T + 0''.051028T^2 + 0''.00052413T^3,$$

where T is the number of centuries. This cannot be extrapolated beyond 4000 years. It may be seen that the shift is about 1° over 4000 years and therefore, barely noticeable in 500 years. There are not many observational details available for measuring the shift of the ecliptic pole. Therefore, it is a puzzle as to how this was determined and introduced in the catalogue. That leads us to the question – is Nityānanda indicating the shift of the pole of ecliptic? If so, how was this observed? Or, is it a mere mention of the position of the pole between these two stars?

Avoiding speculations, a plausible explanation is that Nityānanda identifies χ Dra as the bright star close to the ecliptic pole (*Dhruvākṣa*/ध्रुवाक्षः) and δ Dra as the star to the east of or before the ecliptic pole (*Pūrva-Dhruvākṣa*/पूर्वध्रुवाक्षः). The stars χ Dra and δ Dra are important because the ecliptic pole lies almost on the straight line connecting them.

Conclusion

We have presented a list of stars grouped under Cancer and Leo. Although the coordinates have yielded correct identification for most of the stars, it is not true for the faint star *Puṣya*/पुष्यः. The description that it looks like a cloud is in agreement with the star cluster Praesepe rather than the star delta Cancri, and it also corroborates with the idea that the list was prepared based on actual observations. Names for the bright stars ζ Pup and γ Vel are found as *Naukā*/नौका and *Bhujaṅga*/भुजङ्गः respectively (hitherto unknown). While the former appears to have been derived as a translation (Puppis means the stern of a ship), the latter appears to be an original Sanskrit name. We also notice two stars as markers of the poles of the ecliptic. The words used *Dhruvākṣa*/ध्रुवाक्षः and *Pūrva-Dhruvākṣa*/पूर्वध्रुवाक्षः correspond to stars χ Dracnis and δ Draconis respectively. It is not clear if the words mean the poles of the past and present, or their location to the east and west of the pole. It has also been possible to suggest corrections to the illegible names from the catalogue of astrolabes. Some new names have been identified in the rete. A physical measurement will give the coordinates of these stars precisely and help in their identification.

1. Venketeswara Pai, R. and Shylaja, B. S., *Curr. Sci.*, 2016, **111**, 1551–1558.
2. Burgess, E., *J. Am. Orient. Soc.*, 1860, **6**, 141–498.
3. Abhyankar, K. D., *Pre-Siddhantic Indian Astronomy*, ISERVE, Hyderabad, 2002.
4. Shylaja, B. S. and Venketeswara Pai, R., *Curr. Sci.*, 2018, **115**, 570–573.
5. Colebrook, H. T., Annual Report of the Royal Astronomical Society, 1807, pp. 323–376.
6. Ray, J. C., *Siddhāntadarpaṇa* of Chandraśekhara Sāmanta, Institute of Orissan Culture, Bhubhaneshwar, 1998.
7. Pingree, D., In *Dictionary of Scientific Biography*, 1978, vol. 15, pp. 533–633.
8. Raika, K. K. *Edition of Yantrarāja and its Commentary by Malayendu Sūri*, Nirnayasagar Press, Mumbai, 1936.
9. Manuscript of *Siddhātarāja*/*Sarvasiddhāntarāja* by Nityānanda, No. 206 of A.1883-84, Bhandarkar Oriental Research Institute, unpublished, Pune.
10. Ohashi, Y., *Indian J. Hist. Sci.*, 1994, **29**(2), 155–313.
11. Venketeswara Pai, R., Ramasubramanian, K., Sriram, M. S. and Srinivas, M. D., *Karaṇapaddhati of Putumana Somayājī, with Translation and Detailed Mathematical Notes*, Springer, Singapore, 2018.
12. Venketeswara Pai, R. and Shylaja, B. S., *Curr. Sci.*, 2019, **117**(8), 1383–1386.
13. Sarma, S. R., 2018; https://srsarma.in/catalogue.php
14. Shylaja, B. S. and Venketeswara Pai, R., In *Growth and Development of Astronomy and Astrophysics in India and South Asia-Pacific Region* (eds Orchiston, W., Sule, A. and Vahia, M. N.), Hindusthan Book Agency, 2018, Springer, 2019, pp. 54–58.
15. Liske, J. H., Lederle, T., Fricke, W. and Morando, B., *Astron. Astrophys.*, 1977, **58**, 1–16.
16. *The Indian Astronomical Ephemeris*, Positional Astronomy Centre, Kolkata, 2019.

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