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UNAMBIGUOUS IDENTIFICATION OF THE STAR *ĀRDRĀ*

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Abstract: The names of the stars in old Indian texts are listed in the manuals for the use of astrolabes—for example in the *Yantrarāja, Sarvasiddhāntarāja and Yantra Kiraṇāvalī*—with coordinates and magnitudes. They were forgotten and the names of the stars too were forgotten, leading to confusion in the identification of stars in recent years. Betelgeuse is omitted in the list of 27 bright stars in the old texts. Recent studies have associated it with *Ārdrā*, while the coordinates from the old manuals clearly point to γ Gem (Alhena).

Keywords: Star names from India, *Ārdrā*, Betelgeuse, g Gem

1 INTRODUCTION

Stars in the sky have provided inspirations for the inquisitive human mind from time immemorial. Many of the names for stars and constellations have survived for thousands of years. Here we review a few of them in the context of Indian astronomy and tradition.

The motion of the Moon day-by-day needs references in the sky as markers, a function efficiently achieved by the stars. Thus, there are 27 stars known to Indians for over 5000 years (Abhyankar, 1998; Dikshit, 1895; Saha and Lahiri, 1955). The same set is used for the Sun as well. This is very well established, as depicted by various cultural practices.

One of the oldest records on star names can be traced to the *Mahābhāratha* dated to 3100 BCE based on the association of the star cluster *Kṛttikā* (Pleiades) with the vernal equinox (Dikshit, 1896). We provide two examples among many. One is drawn from the epic *Mahābhāratha*, Arjuna, one of the Pāndavās, and is named *Phālguni*. *Purvā-Phālguni* is the name of the star θ Leo and that of *Uttarā-Phālguni* is β Leo. Another example is that of the names of the kings of Tiruvananatapuram. One of them who was also an astronomer and established an Observatory in the nineteenth century is *Svāti Tirunāl* (Orchiston and Kapoor, 2023). Here *Svāti* refers to Arcturus (α Boo). It is a common practice to name children after the 'birth' star (the star in conjunction with Moon on that day). Even today, birthdays are celebrated on the day corresponding to the position of the Moon.

The motion of the Sun through the year is reckoned by the names of the same 27 stars in a unique way. The rains are named after the stars for their association with the Sun (Shylaja, 2023). The activity of the monsoon is reflected in the proverbs associated with the names of the stars. For example, a proverb states "A good Ārdrā rain is a boon; there is no famine." Here *Ārdrā* is the name of the sixth star in the list of 27. The rain corresponding to this (when the Sun is near this star, in May–June) is very intense and promises a good yield for the farmer.

The names of these 27 stars have blended into the culture, tradition and folk literature in regional languages other than Sanskrit. The same star will have multiple names—*Ārdā* for example has been called *Rudra*.

2 NAMES OF STARS AS CITED BY ASTRONOMERS

Astronomers have used the stars for measurement of time units also. The interval between the stars (dots in the sky) is divided into four parts to serve as time markers. The time of birth mentioned in the horoscope specifies what the quadrant the Moon was at that instant of time. To distinguish the two schemes of names, the dots in the sky are referred to as *yoga tārās* (Balachandra Rao, 2000), which roughly translates as 'stars of conjunction'.

The celestial events of conjunction get special attention in almost all astronomy treatises. A chapter is dedicated to the calculation of instants of conjunctions of the Moon and planets. It has an additional table giving the coordinates of the 27 stars. The procedure for the calculation of conjunctions with stars is essentially the same; the explanation extends the method of calculation to these points in the sky which have no motion of their own. Thus, we find star list with coordinates in almost all texts. Generally, they are reproduced from an older text

Table 1: Inscriptions with records of conjunctions with Aldebaran

Date as Given in Records	Epigraphical Record Details	Event with Corrected Date
28 October 1032	Epigraphia Carnatica Volume III Mysore, Nanjangudu nos. 164 and 165	23 October 1032 Moon with Aldebaran
2 October 1117	EC-VI, Mysore, K R Pete Part II, no. 66	10 October 1117 Saturn next to Rohini (Aldebaran)
1233?	EC-XII, Chikkanayakanahalli, Tumakuru, no 31	1 May 1234 Moon with Aldebaran (Rohini)
18 May 1235	EC-VII, Mandya, no. 29	Moon with Aldebaran (Rohini)
28 December 1286	EC-VII, Mandya, no. 41	Moon with Aldebaran (Rohini)
24 September 1310	EC XIV, Gundlupete, no. 131	14 September 1310 occultation of Aldebaran or 12 October 1310 grazing occultation
3 April 1679	EC VIII, MAR (1944-29), Nanjanagudu	13 April 1679 occultation of Aldebaran

(for example, the *Sūryasiddhānta*) without adding any correction for precession. They were used for checking the coordinates, perhaps on a celestial globe. The conjunctions were indeed observed as verified from the records of stone inscriptions (Shylaja and Geetha, 2021). Table 1 lists some examples of conjunctions of the Moon with Aldebaran.

We have yet another reliable source of the coordinate measures of stars, namely the manuals prepared for using astrolabes. These handy gadgets entered the arena after the twelfth century. The earliest description is in the text called *Yantrarāja* (king of instruments) by Mahendra Sūri in the thirteenth century, with a commentary followed by Malayendu, a little later (Sarma, 2018). We studied an elaborate version of the manual *Sarvasiddhānta rāja* by Nityānanda of the fifteenth century and identified 106 stars (Shylaja and Venketeswara Pai, 2018; Venketeswara Pai and Shylaja, 2021). This list has the brightness measures also. We found many names hitherto unknown. Since the coordinates and magnitudes are available, we were able to identify the stars without ambiguity.

One astrolabe in the compilation of the astrolabes by Sarma may be considered special. Constructed in the year 1605, it has recorded the supernova of 1604. A new name *dhanuśarāgra* (tip of the arrow of Sagittarius) has been engraved. It has been coined to mean "Star near the tip of the arrow of Sagittarius." In recent years, an attempt to trace the optical counterpart resulted in a misidentification; the catalogue identifies it as σ Sgr. We were able to identify it with Kepler's supernova (Shylaja, 2019).

3 IDENTIFICATION OF THE 27 STARS OF THE ZODIAC

Since there is a subtle difference in the coordinate system *Dhruvaka–Vikṣepa* used in Indian texts and the Right Ascension–Declination system, our first effort was to arrive at a suitable transformation. The trigonometrical identities have been worked out by Abhyankar (2006) and Hari (2006); however, we found a systematic increase in the error as one moves north or south. To establish the scheme, we verified the conversions with the well-identified 27 stars of the zodiac (Venketeswara Pai and Shylaja, 2016).

There was no ambiguity in the case of bright stars like Aldebaran (*Rohiṇī*), Regulus (*Maghā*) and Antares (*Jyeṣṭhā*). Fainter ones, however, posed questions, for example, why λ Ori was preferred over α Ori, which is much brighter? Why λ Aqr was preferred over α Gru, since α Boo has been accepted in spite of a larger declination? Such questions had also been raised earlier (Abhyankar, 1991; Neogi and Vahia, 2019; Sule et al., 2006).

The first attempt to identify them with Western star names was attempted by Colebrook (1807). Subsequent efforts in the colonial period supported the identifications.

Although most of the identifications were free of errors, the case of *Ārdrā* is peculiar. It has been identified with α Ori by Colebrook and later astronomers. The 27 stars are approximately 12° apart, matching mean daily motion of the Moon. However, λ Ori as *Mṛgaśira* and Betelgeuse as *Ārdrā* are just 5° apart, as shown in Figure 1. Abhyankar (1991) pointed out the ambiguity and suggested the γ Gem is a better choice. Interestingly, we found that the texts *Yantrarāja* (Mahendra Sūri), *Sarvasiddhāntarāja* (Nityānanda) and *Yantrakiraṇāvali* (Padmanābha) all point to γ Gem rather than α Ori. Much earlier Pingree (1978) identified it with α CMi, which is incorrect as evident from the Figure 1. In spite of these studies, it should be noted that *Ārdrā* is still being misidentified with α Ori in recent discussions (e.g. see Sule and Joshi, 2023).

The list by Padmanabha in the *Yantrakira-*

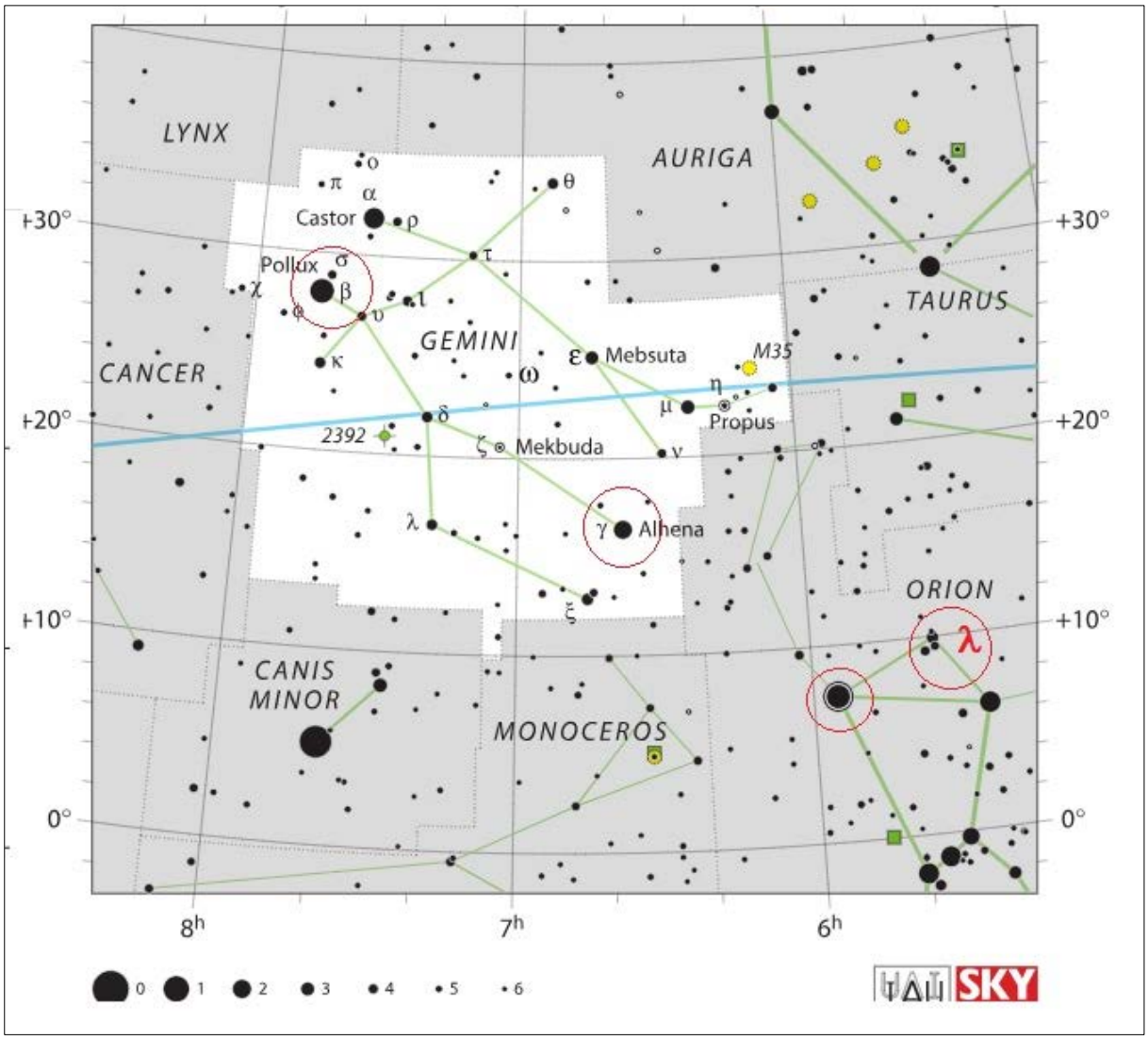

Figure 1: The chart of Gemini from the IAU depicting the stars discussed in the text, which are within red circles. The *yogatarā*s (from the list of 27stars) are generally spaced apart by about 12°. We find that λ Ori and α Ori, the bright star next to it are too close. Alhena is a better choice even on visual inspection. The bright star in Canis Minor is α CMi.

ṇāvali (1500CE) lists another name, *Saurokta-rudra* (which can be confused with *Ārdrā*), but this matches β Tau. This name literally means "That star called *Ārdrā* cited in the *Sūryasid-dhānta.*" (Ohashi, 1994).

The question of λ Ori as *Mṛgaśira* led us in a different direction. It is rather faint and α Ori could have been chosen instead, allowing for an error by a couple of degrees. Another intrigu-ing factor is the absence of identification of Betelgeuse in these star lists. This makes us wonder if these two stars had different bright-nesses 1000 years ago.

4 FOUR CATEGORIES OF STAR NAMES

As discussed by Shylaja and Venketeswara Pai (2019a; 2019b; 2019c; 2019d) and Venket-eswara Pai and Shylaja (2016; 2019; 2020; 2021), the names of the 106 stars can be as-signed to four categories:

(1) Names translated from the Arab / Persian sources
(2) Names coined to match the imaginary fig-ures
(3) New names not found in any text earlier
(4) Isolated names of stars in other forms of literature

For category (1) the best example is Algol (β Per). Its name is given as *mānuṣa śīrṣa* (Rasul-gol, head of a human) in the *Yantrarāja* and the catalog of Malayendu, while the *Sarvasiddhān-tarāja*, by Nityananda, gives *pretaśira* (head of a ghost); both are probably derived from the Arabic name.

For category (2), we have the example of α Gem, which have been translated as *Prathama bāla śīrṣa* (head of the first boy). Another ex-ample is *Nauka* (ship) for ζ Pup.

For category (3) we have the name for α Eri (end of the river) named as Yama, the God of the world of dead people. There are three different names for α Aur, all involve the number 6 as associated with the Deity with six heads—*Ṣadāsya, Skanda, Ṣaṇmukha*—which are different names of the same Deity.

Optical pairs are simply called *yugma* (couplets). The three double stars of UMa are all called *yugmaka* and together they are called *Trivikrama*.[1] Interestingly, the same three stars also have a similar name in Chinese literature (Yang, 2023).

For category (4), we have an example from another source. The dictionary / encyclopaedia of Sanskrit called *Amarakośa*, lists the name *Ilvala* for the three stars in the belt of Orion (see Figure 2). The star catalogues do not list this name—the only exception being the work of Pathāni Chandrasekhara Sāmanta (1835–1904), the last traditional astronomer, who was untouched by the advances of telescope usage in the colonial period (Naik and Satpathy, 1998).

5 THE INFLUENCE OF COLONIAL ASTRONOMY

The texts *Yantrarāja, Sarvasiddhāntarāja and Yantrakiraṇāvali* were almost lost for a couple of centuries, and the traditional star names were forgotten. During the colonial period, scholars transliterated the names provided by European astronomers and eventually they became very popular.

Although the telescopes were brought to India in the early part of seventeenth century (Kapoor, 2019), the establishment of observatories was a rather slow process (Ansari, 1985; Kapoor and Orchiston, 2023). Other than isolated cases of the use of telescopes for celestial events like transits, eclipses and comets, their primary use was to establish the latitude and longitude of various places (Kochhar, 1991). Travellers' records mention that the capital of the Keladi Kingdom in southern India was Ikkeri (Shylaja, 2009a).

Madras Observatory was established in 1786 and evolved into an international solar observatory in the next 100 years (see Kochhar and Orchiston, 2017). There was a paradigm shift in the educational system, with Western scholars teaching astronomy along with subjects like English and mathematics (Venkateswaran, 2007). These developments ought to have helped in blending the two streams; this was not easy in spite of the efforts by a few who were conversant with both systems, such as Chintamani Raghoonathacharry of Madras Observatory (Shylaja, 2009b; Venkateswaran, 2009).

The literature in regional languages started introducing translations of many popular books of astronomy. In the context of this paper four authors are relevant: Bal Gangadhar Tilak (1856–1920), Venkatesh Bapuji Ketkar (1854–1930), Kalinath Mukherjee and more recently, R.L. Narasimhaiah (1902–1969).

In his famous book *The Orion or the Antiquity of the Vedas* Tilak (1893) deals with the precession corrections to date the Mahabharat epic. He further identifies a star near the belt of Orion as *Mṛgaśira*, as shown in Figure 2. The name *Ilvala* also appears near the three stars of the belt of Orion and the name *Mṛgaśira* is marked just below the belt. The star Betelgeuse is marked as '*Ārdrā*'.

Ketkar (2008) was well versed with trigonometry and the European methods. Following Colebrook, he identifies *Ārdrā* with Betelgeuse. In his book *Jyotirgaṇitam* there are Indian names for several stars, whose roots remain unknown. The origin of the names is not specified anywhere in the text, leading us to conclude that he coined them. He authored a book with the same title in Marathi to impress upon local astronomers the need to learn trigonometry, and the names are included there too.

The books by Tilak (1893) and Ketkar (2008) had a strong influence in societal and cultural contexts, and later books used their names extensively.

Kalinath Mukherji had a good exposure to astronomy through the barrister M.J. Herschel, a grandson of Sir William Herschel. In his *Popular Hindu Astronomy* Mukherji (1905) acknowledges M.J. Hershel in the Preface, and even dedicates the book to him. In this book Mukherji names the stars in a unique style. This can be considered as more of a literary exercise rather than for any practical use. This is a translation of the original work in Bengāli.

The impact of British education can be traced in all other Indian languages. The first book in Kannaḍa was by Raghoonathacharry (see Shylaja, 2012), who also wrote in Tamil, Persian and Telugu. In the context of names of stars, a Kannaḍa book by the eminent physicist R.L. Narasimhaiah in the middle of the twentieth century becomes important. It was an attempt to re-introduce astronomy, which had perhaps disappeared from textbooks by then. He wrote the book in a lucid style and christened all the bright stars (other than the 27) with names drawn from epics and puranas (see https://archive.org/details/unset0000unse_r0d9). The book had a great impact, and these names are quite popular.

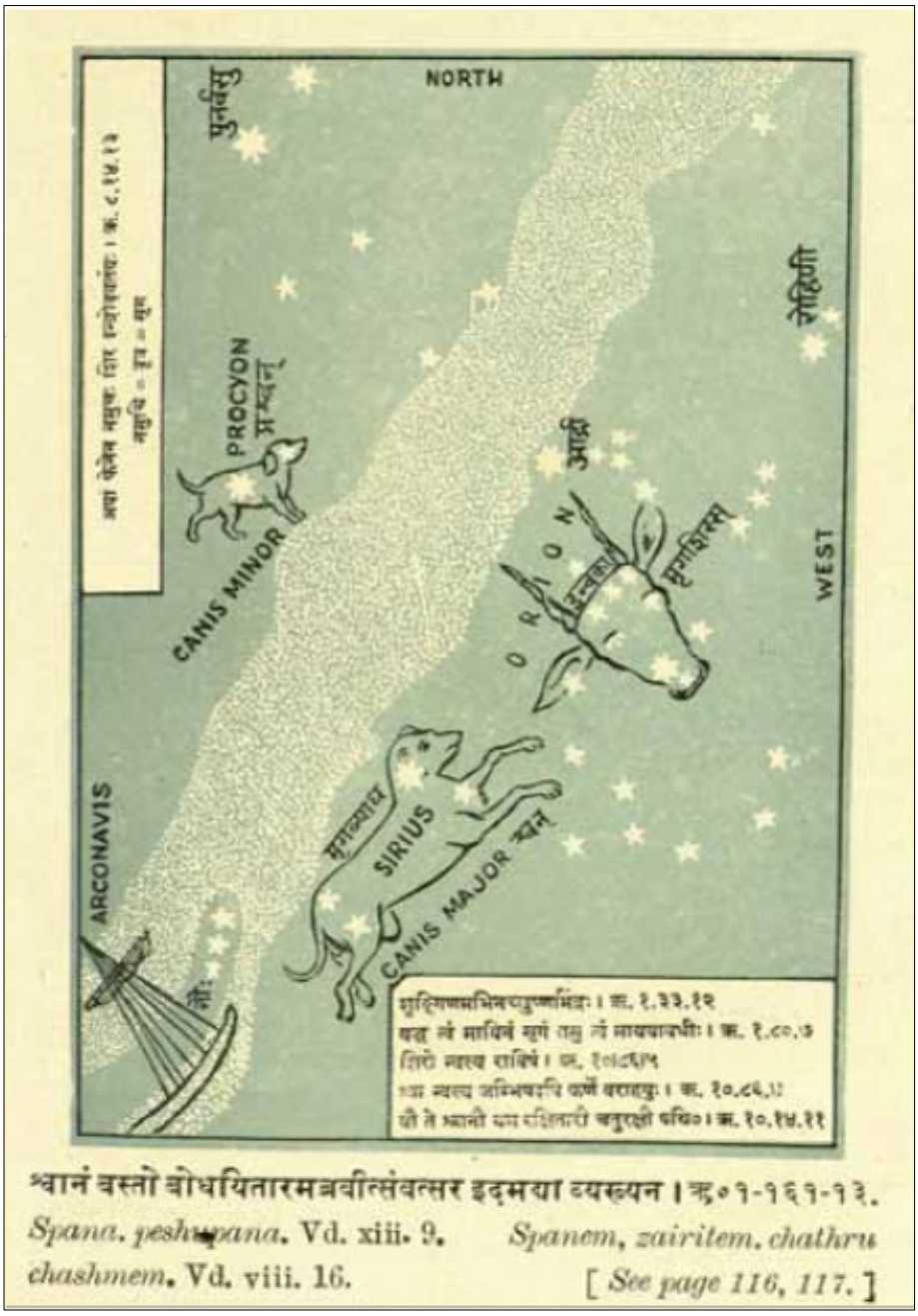

Figure 2: The identification *Mṛgaśira* and *Ārdrā* by Tilak (1893); reproduced from the online version. Note that *Mṛgaśira* is marked near the belt of Orion.

All of these authors were unaware that the stars had indigenous names listed in earlier Indian texts. Perhaps they did not have access to these works, where star names are listed with coordinates. Thus, there is a discrepancy, because the names of the stars as known today in different regions of India do not tally.

IAU Commission C is responsible for compiling star names from different cultures. The names from India are needed with coordinates and if available, magnitude estimates. Therefore, it is important that older texts be studied in detail so that the identities are established without ambiguity.

6 CONCLUDING REMARKS

The names of the stars in Indian texts have generally been restricted to the 27 that lie along the zodiac and were coined for marking the daily movement of the Moon. The *Yantrarāja, Sarvasiddhāntarāja and Yantrakiraṇāvali* texts were written as manuals for the use astrolabes, and have many star names, indigenous and translated, with coordinates and magnitudes. They were almost lost for a couple of centuries and the names were forgotten. During the colonial period, scholars transliterated the names provided by European astronomers, and eventually they became very popular. In the process,

there has been some confusion over the identification of specific stars. It is intriguing to note that the bright star Betelgeuse is not in the list of 27 in the old texts. Recent studies associate it with *Ārdrā*, but the coordinates clearly point to Alhena, γ Gem.

7 NOTES

1. The associated story is about the fifth *avatār* (incarnation) of Lord *Viṣṇu* as a small boy. He asked for three steps (presumably as land), which immediately were granted. He grew to a huge size, and one step encompassed the entire Earth, the second, the entire sky, with no space left for the third step. The donee offered his head for placing the third step and was eventually pushed to *pātāla,* the underworld.

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Shylaja also studied comets (including 1P/Halley), metallic line stars and cataclysmic variables (CVs). The rapid oscillations of the CVs were recorded with a fast photometer that was designed to record lunar occultations. She also studied the signatures of winds of the massive stars in the infra-red while at the Physical Research Laboratory in Ahmedabad.

After joining the Jawaharlal Nehru Planetarium in Bengaluru in 1994 she began studying historical aspects of Indian astronomy. She translated into English the monograph about the 1874 transit of Venus written by Chintamani Ragoonatha Charry in Kannada, a language of South India; this throws light on the techniques used by the Indian astronomers of that era. She has also written many books in Kannada and in English. These include books on the transit of Venus and a book on understanding Jantar Mantar, with pop up pages. She has studied the temples of India for their astronomical significance.

Shylaja has found a new source of astronomical records—stone inscriptions—all over India and South Asia. Her book *History of the Sky – On Stones* (2016) is a compilation of the eclipse and planetary conjunctions cited in these inscriptions. They have been found very useful in that they extend back more than 1500 years. She has also published a translation, with commentary, of the seventeenth century manuscript *Gaṇitagannaḍi: Mirror of Mathematics* (2020, co-authored by Seetharama Javagal).

As a former observational astrophysicist Shylaja also has studied the records of observations of stars from various texts and from the traditions of the navigators, with the aim of deducing the earlier observational techniques that were prevalent in India.

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Venketeswara Pai's broad area of research is the history of science, with a research focus on 'The History and Development of Astronomy and Mathematics in India from the Twelfth to the Seventeenth Century AD'. His particular expertise resides in deciphering scientific manuscripts written in Sanskrit and Malayalam.

He is currently researching the history and development of the *Vākya* School of Astronomy as well as Bhāskara's innovations by studying his auto-commentary known as "*Vāsanā-Bhāṣya*" (in collaboration with Professor M.S. Sriram of Chennai). which will throw some light on the advancement of Indian astronomy in the twelfth century AD.

In 2014 Dr. Pai won the INSA Medal for 'Young Historian of Science', and he is a founding member of the Indian National Young Academy of Science (INYAS).