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ORIGINAL PAPER

Transit of sun through the seasonal *nakṣatra* cycle in the *Vṛddha-Gārgīya Jyotiṣa*

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Abstract

Vṛddha-Gārgiya-Jyotiṣa (*VGJ*) is an important text of Indian astral sciences before the astronomy texts of the Common Era. Only a few of the chapters of this text have been edited and published so far. The present paper reports an important study of two sections of this text which describe the transit of Sun along the 27 asterisms (*nakṣatra)* during the six seasons beginning with winter. The first section called *Ādityacāra* describes each season to be covered by Sun travelling 4½ asterisms starting from *śraviṣṭhā nakṣatra* at the beginning of *śiśira ṛtu* reckoned as the winter solstice day. The seasons are stated in terms of Sun transiting the beginning, middle and end of nine asterisms some of which are made of more than one star. The second section of the text known as *Ṛtusvabhāva* starts with the *vasanta ṛtu* and names twelve asterisms through which Sun transits in the 12 months of the tropical year. It is shown that the solar transit information in the *Ādityacāra* and the *Ṛtusvabhāva* chapters of *VGJ* can be dated, for minimum observational error, to *c* 1300 BCE and *c* 500 BCE respectively.

Keywords Ancient India · Astral sciences · *Pre-siddhāntic* astronomy · Seasonal asterisms · *Vedāṅga Jyotiṣa*

1 Introduction

Vṛddha-gārgīya Jyotiṣa (*VGJ*) is an ancient encyclopedic text, originating several centuries before the more popular *saṃhitā* text, the *Bṛhatsaṃhitā* (*BS*) of Varāhamihira (sixth century CE). Several manuscripts attributed to Garga, Vṛddha-garga, Gārgya, Gārgīya and other variant names are available to differing levels of accuracy and readability. Such manuscripts are yet to be edited and published in readable form to properly understand and appreciate the contribution of the Vṛddha-garga or Garga School of Indic astronomy before the proliferation of *Siddhānta* texts of mathematical astronomy from around the beginning of the Common Era (CE).

Existence of the school of Vṛddha-Garga (VG) and/or Garga has been known for a long time. Dikshit (1896) and Sudhākara Dvivedi (1908) drew the attention of modern scholars to the text of Garga quoted by Somākara (7th century?) in his commentary on the calendar text of Lagadha in support of sun being with *śraviṣṭhā nakṣatra* on the winter solstice day. This observation of *śraviṣṭhā* (later known as *dhaniṣṭhā*) epoch of winter solstice seems to have been transmitted over centuries as a memorized standard. Varāhamihira in *BS* writes that as per ancient treatises the winter solstice occurred once upon a time with sun in *dhaniṣṭhā* asterism.[1] Varāhamihira refers to both Parāśara and Vṛddha-garga by name in several places, but not specifically to their winter solstice data. Bhaṭṭotpala (9th–10th century) the commentator of *BS* quotes extensively from Vṛddha-Garga and Garga, but attributes the above *dhaniṣṭhā* observation to Parāśara, further adding that it must have been an *utpāta* or an unprecedented anomaly.[2] He quotes from the prose text of *Parāśaratantra* (*PT*) to the effect that the transit of sun started from *śraviṣṭhā* at the beginning of the winter season, taken as the winter solstice day, to pass through the six seasons at the rate of 4½ *nakṣatra* (asterisms) per season. It is interesting to note that *VGJ* the text under study in the present paper, contains the same seasonal transit in versified form in one place, but towards the end of

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[1] आश्लेषार्धाद्दक्षिणमुत्तरायणं रवेर्धनिष्ठाद्यम् । नूनं कदाचिदासीद्येनोक्तं पूर्वशास्त्रेषु ||*BS* (3.1).

[2] तत्र रवेः आदित्यस्य आश्लेषार्द्धात् सार्पान्त्यपादद्वयाद्दक्षिणमयनं तथा धनिष्ठाद्यं वासवप्रारम्भमुत्तरमयनं नूनं निश्चितं कदाचित् उत्पातवशात् आसीत् अभूत् । येन पूर्वशास्त्रेषु पाराशरादिषु उक्तं कथितम् । नूनमनुमाने वा || (Commentary of Bhaṭṭotpala on the above verse).

the compilation describes a different transit for each month of the solar year. *VGJ* states matter-of-fact invisibility day numbers for planets and realistic periods for eclipses and description of a sequence of comet appearances with details of rise and transit in the background of the stars. The present study is limited to a brief review of sun's transit as given in two sections of *VGJ* named *Ādityacāra* and *Ṛtusvabhāva.* Analysis of this information helps one in estimating the historical origin of the School of Vṛddha-Garga, known as Vṛddha-gārgīya or just the Gārgīya tradition, before the Common Era (BCE).

2 Manuscripts of *VGJ*

The manuscripts of *VGJ* referred to by some as *Gārgīya-jyotiṣa*, are heavily layered with the most ancient and the relatively later parts mixed up. Since the available manuscripts are reproductions of previous versions, scribal errors are quite large in some copies. Additionally, some of the chapters in whole or in part seem to be added by the followers of the tradition of *VG* in the early centuries of the Common Era. Notwithstanding such difficulties a timeline of development of observational astronomy can be deciphered in *VGJ*. Pingree (1971) lists more than ten versions of *VGJ*, popularly known as *Vṛddha-garga-saṁhitā,* available in the manuscript libraries in India and abroad. Previously Mankad (1951), Mitchener (1986), Geslani *et al* (2017), Mak (2019), Iyengar *et al* (2019) have reviewed these manuscripts from differing perspectives and in varying details. At present only certain select chapters extracted from the manuscripts have been edited and published. Broadly, it is known that the astral sciences part of *VGJ* contains ideas and theories of ancient Vedic thinkers, generally followed by later astronomers. Thus, the importance of *VGJ* for tracing history of science in general and of Hindu astral sciences in particular can never be over emphasized.

3 *Ādityacāra:* sun's transit

The astral science tradition expounded in *VGJ* is organized in 24 *aṅga* (section) and 40 *upāṅga* (sub-section), each such section having one or more *adhyāya* (chapter). Sun's transit among the 27 *nakṣatra* circle forms the 11th section with a single chapter. There are 135 verses in this chapter, as narrated by Garga to Nārada, largely devoted to qualitative description of sun's orb, shape, colour, weather changes, characteristics of seasons and portents for good and deficient rainfall. Among these are six verses, one each for the six seasons that state the position of sun among the *nakṣatra* starting from the beginning of the *śiśira-ṛtu,* which is winter. This implies that the Vedic Year started on the winter solstice day with the sun starting to move north, from its extreme southern declination. Each season is stated to cover 4½ *nakṣatra* stretches starting from *śraviṣṭhā.* One could easily see that this is same as the seasonal solar zodiac stated in the *Parāśara Tantra* (*PT*). The difference between the two is only in the style and not in the content. Parāśara's statement is in prose known to us through quotations by later authors (Iyengar, 2013). *VGJ* gives the same information in versified form. The six verses are as follows:

श्रविष्ठादीनि चत्वारि पौष्णार्धञ्च दिवाकरः ।
वर्धयन् सरसस्तिक्तं मासौ तपति शैशिरे ॥
रोहिण्यन्तानि विचरन् पौष्णार्धाद्याच्च भानुमान् ।
मासौ तपति वासन्तौ कषायं वर्धयन् रसम् ॥
सार्पार्धान्तानि विचरन् सौम्याद्यानि तु भानुमान् ।
ग्रैष्मिकौ तपते मासौ कटुकं वर्धयन् रसम् ॥
सावित्रान्तानि विचरन् सार्पार्धाद्यानि भास्करः ।
वार्षिकौ तपते मासौ रसमम्लं विवर्धयन् ॥
चित्रादीन्यथ चत्वारि ज्येष्ठार्धञ्च दिवाकरः ।
शारदौ लवणाख्यं च तपत्याप्याययन् रसम् ॥
ज्येष्ठार्धादीनि चत्वारि वैष्णवान्तानि भास्करः ।
हेमन्ते तपते मासौ मधुरं वर्धयन् रसम् ॥
(*Ādityacāra*; v. 47, 48, 52, 53, 54, 55)[3]

The text is more detailed about the environmental features and changes that occur in the seasons but the sun's positions are stated crisply with only the starting and ending parts of the respective *nakṣatra*. In the above six verses the astronomical content is limited to the first half of each verse. The second half states the name of the season of 2-month duration. The month names are not mentioned. The gist of the text is as follows.

> Sun's transit starting from *śraviṣṭhā nakṣatra* till *half-revatī* is the *śiśira-ṛtu*; from *half-revatī* to end of *rohiṇī* is the *vasanta-ṛtu*. Sun's course from the beginning of *mṛgaśiras* till *half-āśleṣā* is the *grīṣma-ṛtu*; from *half-āśleṣā* till end of *hasta* is the *varṣa-ṛtu*. Sun's travel from the beginning of *citrā* till *half-jyeṣṭhā* is the *śarad-ṛtu*; from *half-jyeṣṭhā* ending with *śravaṇa* is the *hemanta-ṛtu*.

Here, as in the *Parāśara Tantra*, the seasons are linked to the position of sun with respect to stars visible in the background. This is in contrast to later *siddhānta* astronomers defining seasons in terms of the twelve signs or *rāśi*.

In *VGJ* the winter starts with sun in the asterism *śraviṣṭhā* denoted as *dhaniṣṭhā* in later texts. Each of the seasons is 61 days long, equal to one-sixth of the year of 366 days. The three seasons of *śiśira, grīṣma* and *śarat* start with sun

[3] The numbering of the verses here and later follows the sequential order in the manuscript no.Th.319 of the National Library of India, Kolkata. The text presented has been edited for correctness and readability by comparing it with six other manuscripts.

respectively in *śraviṣṭhā, saumya (mṛgaśiras)* and *citrā*, to extend up to the middle/half of *pauṣṇa (revatī), sārpa (āśleṣā),* and *jyeṣṭhā* respectively. The subsequent seasons *vasanta, varṣa,* and *hemanta* are stated to continue from the same half-points of the above three asterisms, but are said to end with sun in *rohiṇī, hasta* and *śravaṇa* respectively.

Vedic astronomers had long recognized that seasons follow the sun and had qualitatively characterized them in terms of annual periodicity of felt weather, sky features, environmental conditions and social behaviour.[4] Observation of the early morning rise of auspicious *nakṣatra* for performance of house hold rites as enjoined in the *Taittirīya Brāhmaṇa* (*TB*)[5] and the recognition of *maghā*, *śraviṣṭhā* and *sārpa* as the background *nakṣatra* for defining the southern and northern transit of sun in the *Maitrāyaṇīya Āraṇyaka Upaniṣat* (*MAU*) are the easily traceable beginnings of the formation of the Vedic solar zodiac.[6] *MAU* says that the fiery southern transit of sun is in direct order from beginning of *maghā* till *śraviṣṭhārdha* and the milder northern transit is in the *reverse order* from beginning of *sārpa* to *śraviṣthārdha*. Taken in the direct order the mid-*śraviṣṭhā* (*śraviṣṭārdha)* boundary is common to both the transits. But curiously, the beginning of the southern and the end point of the northern sojourn of sun which should be temporally identical are stated in terms of two spatially distinct but consecutive asterisms. The mention of the beginning and ending *nakṣatra* exhibits a peculiarity that is common to *MAU*, *PT* and *VGJ*. To find the position of sun in a *nakṣatra* with several constituent stars by observation is a difficult task. By observing the star that is just above the horizon before sunrise and similarly noting the same star that is just visible in the west after sun set, one can form an idea about sun's station in a *nakṣatra.* The ending and starting of the seasons are in reality seamless, but here expressed in terms of two different asterisms. We can only speculate that this may be an attempt to relate the end and start of a *ṛtu* with the set and rise of consecutive boundary stars. These texts are the very early specimens of observational astronomy and formation of the Indic solar zodiac, developed over the already existing lunar zodiac. The statements in *VGJ* are verbal expressions for technically equating the temporal extent of 183 days in one *ayana* and 61 days in one *ṛtu* on earth, counted in terms of sun rises, to the visible spatial transit of sun in the sky as a matter-of- fact observation.

Rohiṇī asterism is made of five stars, looking like the Vedic Soma-cart with a triangular plank. The bright star α Tau (Aldebaran) is located at the western end of this figure. The distance between this and the next *nakṣatra* namely, *mṛgaśiras* with three (or five) stars, usually recognized by the middle star λ Ori is about 14°. If the end of spring, when Sun is at 30° longitude, were to be recognized by the early morning rise of *rohiṇī*, it might take another 10–15 days for parts of *mṛgasiras* to be seen in the morning. Thus, when *PT* and *VGJ* declare *vasanta* (spring) ends in *rohiṇī* and *grīṣma* (summer) begins with *mṛgasiras*, a diffuse boundary is implicitly recognized between the above two asterisms. Since *śiśira-ṛtu* by convention started on the day of the winter solstice, sun would have been with the asterism *śraviṣṭhā* (*dhaniṣṭhā* in later texts) theoretically at 270° longitude. Based on this, all the 27 *nakṣatra* sectors, each taken to be 13° 20′ wide, can be figured out and named in their traditional order which has remained unchanged since the Vedic past. The textual statements on the seasons can be taken to be meaningful if the relative positions of the 27 *nakṣatra* sequence remain internally consistent. However, since the *VGJ* text uses phrases such as *rohiṇyanta* and *saumyādi*, without equating the two in space, this internal consistency condition of the 27 *nakṣatra* that are made up of more than eighty stars can be verified only in a statistical sense using a suitable error criterion. Even if the consistency condition gets satisfied, the *VGJ* verses can be taken to be observationally realistic if the named nine asterisms remained coevally visible on yearly basis at or near the season boundaries for a few years in the past. If such a period can be found, it would be a historical bench mark in the practice of astronomy in ancient India.

4 *Nakṣatra* identification

There is considerable literature on the identification of the 27–28 *nakṣatra*, the names of which along with interesting astral lore have come down to us from antiquity. A standard reference for the names of traditional stars and their possible identification with the help of *siddhānta* texts of the Common Era is the Report of the Calendar Reform Committee (Saha & Lahiri, 1955). Some of the *nakṣatra* are star groups and consequently several works exist on the relation between the bright stars with which moon comes in conjunction (*yogatārā*) of the ancient asterisms, their given longitudes in the astronomical texts of the Common Era and attempts at backward projection of such results to the ancient period. There is difficulty in correctly identifying the *nirayana nakṣatra* zodiac of *c* 285 CE, in terms of the Vedic asterisms, which if successful would have helped in knowing the ancient system of Parāśara and Vṛddha-Garga more accurately (Dikshit, 1969; Sen & Shukla, 2000). The sequential order of the *nakṣatra* names starting with *kṛttikā* has remained unchanged, except for the elision of *abhijit* from the original list of 28 asterisms and postulation of average

[4] *Taittirīya Āraṇyaka* (I.3,4,5).

[5] *Taittirīya Brāhmaṇa* (I.5.2).

[6] [...]एतस्याग्नेयमर्धमर्धं वारुणम् । मघाद्यं श्रविष्ठार्धमाग्नेयं क्रमेणोत्क्रमेण सार्पाद्यं श्रविष्ठार्धान्तं सौम्यम् ॥ *MAU* (6.14).

travel time of nearly 13½ days for sun in each *nakṣatra.* As a corollary the stellar circle got divided into 27 equal divisions of 13° 20′ with each *nakṣatra* assigned to its corresponding sector.

Some of the famous *nakṣatras* such as *kṛttikā, rohiṇi, maghā, hasta*, *citrā, svāti, viśākhe, jyeṣṭhā* are identifiable reasonably well in terms of their modern names due to the number of member stars, their geometry and shape as stated in *PT* and other ancient texts. However, the same cannot be said about others such as *aśvayuk (aśvini), bharaṇi, uttarāṣāḍhā,* and *revatī*. The sequential organization of the *nakṣatra* system, though stable by itself, might have suffered disturbances in the assigned eponymous older divisions, due to effect of precession. This introduces uncertainty particularly in the identification of *uttarāṣāḍhā*, *śravaṇa* and *śraviṣṭhā* asterisms near the eliminated *abhijit nakṣatra*, with possibility of positional errors propagating further.

In effect, identification of the winter solstice *nakṣatra* of Lagadha's Vedic calendar (Sastry, 1984) with the star α- or β-*delphini* and consequent dating of his work to *c* 1300 BCE is not as straight forward as it is generally presumed. Abhyankar (1991) pointed out this problem and also suggested corrections to the identification of some traditional stars, which will be discussed later. Previously while analysing the seasonal zodiac of Parāśara, the above difficulty of fixing the origin of the circle of seasons, was circumvented by considering only the well-known six *nakṣatra*s namely, *kṛttikā, rohiṇī, maghā, citrā*, *viśākhe* and *jyeṣṭhā* represented by their constituent bright stars further identified in terms of their modern names, for verifying whether their positions as understood from the *yet unidentified śraviṣṭhā* at 270° remain internally compatible. Even though this does not address the textual star statements directly, visibility of the above six stars within their sectors in a year, constrain the possible epoch of *PT* and subsequently of *VGJ* to a narrow band of 1350–1130 BCE (Iyengar, 2014). For this period, it is natural to take the winter solstice star to have been in the Delphinius constellation as demonstrated by Gondalekhar (2013). Now, it remains to verify whether the star boundaries given in our text are consistent with β Del as a proxy for the *śraviṣṭhā nakṣatra* of the seasonal zodiac of *VGJ*.

Here, we face a new difficulty. Both *PT* and *VGJ* characterize the seasons by the *ādi* (beginning), *ardha* (half/middle) and *anta* (end) of the asterisms which have to be some type of limits associated with particular seasons and visible asterisms. Since the *nakṣatra*s are groups made of one to six stars of varying geometrical forms, the boundaries are not at all obvious. We can only surmise that there must have been naked eye spatial markers visualized on the sky by means of an imaginary figure or astrograph made by the particular *nakṣatra* and nearby stars. In any case, for further analysis, it is useful to collect available data on the *nakṣatras* from *VGJ* and a few other ancient texts fixed in the centuries before the beginning of the Common Era. Apart from *PT*, the *Atharvaveda-pariśiṣṭa* (*AVP*), the *Śardūlakarṇāvadāna* (*SKA*) and the *Sūrya-candra-prajñapti* (*SCP*) discuss ancient astral topics including the star list. The three texts *PT*, *VGJ* and *AVP* are in the Vedic tradition; *SKA* and *SCP* are from the Bauddha and Jaina tradition respectively. Information available in the above texts on the number of stars, their objectivised shape and nearest possible modern star names is presented in Table 1. The visual figure of the asterism or astrograph is collected as stated in the texts, given therein as an aid for identification of the *nakṣatra*. In some cases, the Vedic name and its synonym indicates the shape, like the name *hasta* refers to the Corvus constellation looking like a hand or *palm* with five (fingers) constituent stars. *Āśleṣā* called *sārpa* resembles a snake-head. However, SCP sees here the shape of a *dhvaja* or a flag, which is equally possible.

The *Nakṣatropasarga* (occultation and affliction of asterisms) chapter of the *Parāśara Tantra* gives the relative directions of the stars in a *nakṣatra*. This helps in understanding how *rohiṇī* with five stars is figured as *śakaṭa* (cart) and *maghā* with six stars is mapped as *koṣṭāgāra* (enclosure/room). *SKA* and *SCP* also give the star count and the shape of all the 28 *nakṣatras* of their list which is broadly same as in the Vedic tradition with a few exceptions. Some of the picturesque names given to the *nakṣatra* shapes are indicative of the astrograph of such asterisms. For example, in *SCP* the shape of *jyeṣṭhā* with stars α Sco, σ Sco, ε Sco, is named *gajadanta* or elephant tusk which is apt for the bent profile of this asterism. When a *nakṣatra* has only one member, *SKA* and *SCP* denote the figure as *tilaka, bindu* or flower. The astrographs listed in the table are as per the Vedic, *PT* and *VGJ* texts wherever available, otherwise they are taken from *SCP* (marked by a star) which is in some places different from the shapes meant by the Vedic tradition.

It is to be noted that the primary objective of the present study is not identification of the ancient asterisms, but finding the period when the *nakṣatra* of *VGJ* were visibly stationed in their seasonal positions. This in turn depends on how closely we are able to equate the 27 *nakṣatra* of *VGJ* with corresponding star names in current astronomical tables. As a first step the constituent stars of the asterisms with their star catalogue names can be sourced from the works of past authors. These are shown in Table 1, with a few significant differences. The total number of stars making up the twenty-seven *nakṣatra* as per *VGJ* is eighty-three; a system inherited from antecedent sources for tracking the moon.[7] In fact, *VGJ* assigns unequal time for moon to transit

[7] Saha and Lahiri (1955) list 79 constituent stars to represent the 27 asterisms omitting *abhijit*. These largely overlap with the 83 stars of *VGJ* listed in Table 1. Notable differences are in the number of constituent stars making up asterisms 18 to 22. The single star *ārdra* is

Table 1 *Nakṣatra* list with star count, shape, catalogue names, proxy star and *yogatārā*

No	*Nakṣatra*	Star Count					Astrograph	Constituent Stars	Proxy Star (Authors)	*Yogatārā* (Abhyankar)
		VGJ	*PT*	*AVP*	*SKA*	*SCP*				
1	*Kṛttikā*	*6*	*6*	*6*	*6*	*6*	Knife/Cleaver	(17,19,20,23,27,η) Tau	η Tau	η Tau
2	*Rohiṇī*	*5*	*5*	*1*	*5*	*5*	Cart	(α,γ,δ1,ε,θ2) Tau	α Tau	α Tau
3	*Mṛgaśira*	*3*	*3*	*3*	*3*	*3*	Deer's Head	(α,γ,λ) Ori	λ Ori	λ Ori
4	*Ārdrā*	*1*	*1*	*1*	*1*	*1*	*Bāhu* (Arm)	(γ) Gem	γ Gem	γ Gem
5	*Punarvasu*	*2*	*2*	*2*	*2*	*5*	Balance	(α,β) Gem	β Gem	β Gem
6	*Puṣya*	*1*	*1*	*1*	*3*	*3*	*Śarāva* (Pot-lid)	(δ) Cnc	δ Cnc	δ Cnc
7	*Āśleṣā*	*6*	*6*	*6*	*1*	*6*	Snake Head Flag*	(δ,ε,ζ,η,ρ,σ) Hya	ζ Hya	ζ Hya
8	*Maghā*	*6*	*6*	*6*	*5*	*7*	Enclosure	(α,γ1,ε,ζ,η,μ) Leo	ζ Leo	α Leo
9	*P Phalgunī*	*2*	*2*	*2*	*2*	*2*	Half-chair	(δ,θ) Leo	δ Leo	δ Leo
10	*U Phalgunī*	*2*	*2*	*2*	*2*	*2*	Half-chair	(93,β) Leo	β Leo	β Leo
11	*Hasta*	*5*	*5*	*5*	*5*	*5*	Hand	(α,β,γ,δ,ε) Crv	δ Crv	γ Crv
12	*Citrā*	*1*	*1*	*1*	*1*	*1*	Flower	(α) Vir	α Vir	α Vir
13	*Svātī*	*1*	*1*	*1*	*1*	*1*	Wedge	(α) Boo	α Boo	α Boo
14	*Viśākhā*	*2*	*2*	*2*	*2*	*5*	Divider, Rope*	(α1,α2) Lib	α2 Lib	α Lib
15	*Anūrādhā*	*4*	*4*	*4*	*4*	*5*	Necklace	(β1,δ,π,ω1) Sco	δ Sco	δ Sco
16	*Jyeṣṭhā*	*3*	*3*	*1*	*3*	*3*	Elephant Tusk	(α,ε,σ) Sco	ε Sco	α Sco
17	*Mūla*	*6*	*2*	*7*	*7*	*1*	Root Scorpion Tail*	(ζ2,θ,ι1,κ,λ,ν) Sco	κ Sco	λ Sco
18	*P Aṣāḍhā*	*4*	*4*	*4*	*4*	*4*	*Gajavikrama** (Elephant Step)	(γ,δ,ε,λ) Sgr	λ Sgr	δ Sgr
19	*U Aṣāḍhā*	*4*	*4*	*4*	*4*	*4*	*Siṁhaniṣadya** (Lion seat)	(ζ,σ,τ,φ) Sgr	τ Sgr	σ Sgr
**	*Abhijit*	–	*3*	*1*	*3*	*3*	*Gośīrṣāvali**	–	–	α Aql
20	*Śravaṇa*	*3*	*3*	*3*	*3*	*3*	Ear Barley seed*	(α,β,γ) Aql	α Aql	β Del
21	*Śraviṣṭhā* (*Dhaniṣṭhā*)	*4*	*5*	*5*	*4*	*5*	*Śakuni-pañjara** (Bird cage)	(α,β,γ2,δ) Del	β Del	β Aqr
22	*Śatabhiṣak*	*1*	*1*	*1*	*1*	*100*	*Puṣpopacāra** (Flower Boquet)	(λ) Aqr	λ Aqr	α PsA
23	*P Proṣṭhapadā*	*2*	*2*	*2*	*2*	*2*	Cow's Foot	(α,β) Peg	α Peg	α Peg
24	*U Proṣṭhapadā*	*2*	*2*	*2*	*2*	*2*	Cow's Foot	(γ,λ) Peg	λ Peg	λ Peg
25	*Revatī*	*1*	*1*	*1*	*1*	*32*	Canoe*	(ε,α,ζ) Psc	ε Psc	ζ Psc
26	*Aśvayuk*	*3*	*2*	*1*	*2*	*3*	Horse-neck	(α,β,γ) Ari	β Ari	β Ari
27	*Bharaṇī*	*3*	*3*	*3*	*3*	*3*	*Bhaga* (Perineum)	(35,39,41) Ari	41 Ari	41 Ari

the *nakṣatra* stretches. But in describing the six season solar transit, each season is equalized in time and space to be of 4½ *nakṣatra* span. We may infer that for lunar transit of a shorter period, unequal dwell time was more realistic, whereas when sun arrived nearly to the same *nakṣatra* at the solstices, equal division was a natural choice for demarcating the two *ayana* and the six seasons. Such a view is quite explicit in the Sāmavedic *Nidāna Sūtra* which takes sun to spend equal time of 13 and (5/9) days in each of the 27 asterisms.[8] The year is 366 days long as in our text and hence expectation of the stated season boundary to be in the specified *nakṣatra* division of 13° 20′ arc is logical. However due to the extended shape of some asterisms with two to six stars, the member stars may creep into neighbouring sectors. In the literature, including astronomical *siddhānta* texts, the difficulty of multiple stars is handled by defining a junction star (*yogatāra*) usually the brightest member in

Footnote 7 (continued)

taken as α Ori by Saha and Lahiri, whereas VGJ points towards γ Gem.

[8] स एष आदित्यसंवत्सरो नाक्षत्रः। आदित्यः खलु शश्वदेतावद्भिरहोभिर्नक्षत्राणि समवैति। त्रयोदशाहं त्रयोदशाहमेकैकं नक्षत्रमुपतिष्ठति। अहस्तृतीयं च नवधा कृतयोरहोरात्रयोर्द्वे द्वे कले चेति संवत्सराः। ताश्चत्वारिंशच्चतुःपञ्चाशतं कलाः। ते षण्णववर्गाः सषड्विष्टित्रिशतः॥ (*Nidāna Sūtra* V.12).

the asterism. But, when mid-points of the *nakṣatra* form the seasonal limits, it will be convenient to have a representative proxy star that can be followed over time. Accordingly, a few comments on the selection of the proxy stars, particularly those mentioned by *VGJ* as seasonal boundaries, would be appropriate.

The first two *nakṣatra* namely, *kṛttikā* and *rohiṇī* have stood the test of time since their Vedic antiquity and are identifiable easily. The *nakṣatra mṛgaśiras* (*saumyaṃ*) with three (or five) stars is in the Orion constellation. The astrograph as deer's head gets well defined with the α, λ, γ stars of Orion, the first and the third being brighter than the second, but λ Ori forming a vertex joining the other two. The vertex star λ Ori with two nearby dim stars is sometimes called *invakā*. The Yajurvedic *Maitrāyaṇīya Saṃhitā* (*MS*) gives the name *invakā* (*invagam*) for what others call *mṛgaśiras* and states the regent deities as *maruts* and not as *soma*. *VGJ* in the *nakṣatra-karma-guṇa* chapter describes *mṛgaśiras* as *tritāraṁ adhikā saumyam.* Even though the text is not very clear, this may mean one with three surplus stars. The famous lexicon *Amarakośa* characterizes *mṛgaśiras* as that asterism at the head of which *invakā* are stationed.[9] Kṣīraswāmin the commentator of the above lexicon is clear not only about the Vedic name and the deities, but also says *invakā* or *mṛgaśiras* is made of five stars.[10] Hence λ Ori near about the centre of the figure, as the proxy star for *mṛgaśiras* is reasonable. Abhyankar (1991) arrived at the same conclusion through different arguments. This discussion on the ancient asterism *mṛgaśiras* indicates that the identification of the next asterism *ārdrā* with α Ori (Betelgeuse) in the more ancient periods is not tenable. In the *MS* we read *bāhuḥ nakṣatram rudro devatā* in the place of *ārdra.* This means, the single star *ārdra* was located on the arm-like part of a constellation next to Orion, which is Gemini. Hence we have taken this to be the bright star γ Gem, which is same as the revised identification of *ārdrā* by Abhyankar following different arguments. In the case of interpreting the half-limit *sārpārdha, jyeṣṭhārdha,* and *pauṣṇārdha* in the absence of any other clarifications available, we have to select a star near the central part of the asterism figure as the proxy. The representation of the first and the second above with ζ Hya and ε Sco is straightforward since the astrograph with multiple stars is stated in the texts. The selection of ε Psc needs some explanation. *Revatī* is called *pauṣṇaṃ* since *Pūṣan* is the deity of this asterism. All the ancient texts mention only one star for this *nakṣatra*. But, the spatial extent of Pisces constellation, figured as a fish, is large and texts like *SCP* and *BS* mention 32 stars forming the figure of a canoe. Even though this location for *revatī* is an inherited tradition, there is a tenuous link for the fish astrograph in the Vedic texts. In the *Taittirīya Saṃhitā* the Vedic deity of *revatī* namely, *Pūṣan* the leader of animals is characterized as toothless and hence flour balls are prescribed as food offering in rituals.[11] This seemingly harmonizes with the celestial figure of toothless *Pūṣan* to be like fish. In the past literature *revatī* has been identified variously as α Psc, ζ Psc and other stars. Since, there is no mention of separation of stars in terms of angular or other distances in *VGJ*, we take *pauṣṇārdha* as the visible star ε Psc in the middle region of the Pisces constellation.

For sake of comparison, the 27-*yogatārā* identified by Abhyankar for the *vedāṅga* period is listed in the last column of Table 1.

5 Error analysis

The analysis we have to carry out is to check how closely a given *nakṣatra* is located in its predetermined interval corresponding to the *VGJ* seasonal stars. As a first step in this direction the ecliptic longitudes of each of the eighty-three stars constituting the twenty-seven *nakṣatra*s are found for a long period with the help of the Stellarium software. Some stars will satisfy the internal location condition for some years, while many others may not do so over long time periods. To capture this information an error function E is defined as follows. Let, the desired interval of the ith asterism be (J_i to J_{i+1}) and its longitude in a given year ***y*** be L_i (i = 1, 2, …27). The error of location will be zero, if a *nakṣatra* with single star, is found to be in its division; otherwise the lesser of the absolute difference between L_i and the two boundary values J_i and J_{i+1} is the error E_i. That is,

$$
\begin{aligned}
E_i &= 0 \; \mathit{if} \left(J_i < L_i < J_{i+1}\right) \; \mathit{else} \; E_i \\
&= \min\left[\mathrm{abs}\left(L_i - J_i\right),\ \mathrm{abs}\left(L_i - J_{i+1}\right)\right]
\end{aligned}
$$

For a *nakṣatra* with multiple stars there will be more than one sample error value which will be smoothened over the constituent stars to get the mean location error Ei (i = 1, 2…27) in any year. The location error E_y in a given year ***y*** is the average of E_i over all the 27 *nakṣatra*. This quantity is plotted (green broken line) in Fig. 1 for the period of (2500–250) BCE at intervals of 50 years. It is seen that the error curve is smooth and reaches its minimum around 1250 BCE. The mean positional error of consistency for any *nakṣatra* is about 1° during (1500–1000) BCE which is

[9] मृगशीर्षं मृगशिरस्तस्मिन्नेवाग्रहायणी । इन्वकास्तच्छिरोदेशे तारका निवसन्ति याः ॥ (*vyomavarga* 23).

[10] मार्गशीर्षादारभ्य संवत्सरप्रवृत्तेः […] इन्वका इति पञ्चताराः, इन्वन्ति प्रीणन्तीन्वकाः, मरुतो देवता इन्वका नक्षत्रमिति श्रुतेः ॥

[11] पूषा प्राश्यदतोऽरुणत् तस्मात् पूषा प्रपिष्टभागोऽदन्तको हि […] ॥ (*TS* II.6.8.5).

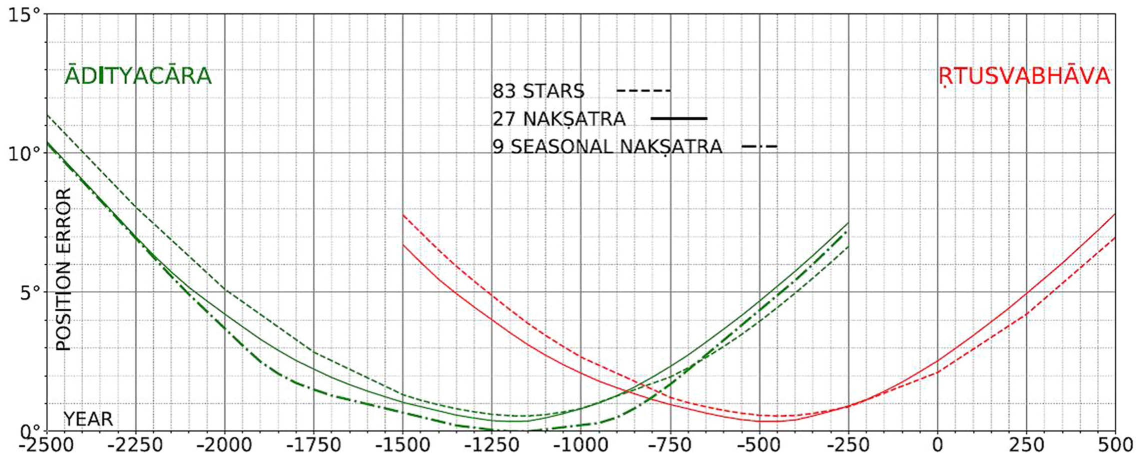

Fig. 1 Yearly variation of the *nakṣatra* location error E_y in the seasonal solar zodiac of *VGJ*. The green curves (....83 stars; —— 27 proxy stars; -.-.-. 9 seasonal *nakṣatra*) refer to the *Ādityacāra* data of the 11th Section of *VGJ*. The 83 constituent and the 27 proxy stars are as per Table 1. Errors for the nine seasonal *nakatra* boundaries remain zero during 1210–1150 BCE. The red curves refer to the 12 month solar *nakṣatra* data available in the 59th section titled *Ṛtusvabhāva*

acceptable for the ancient epoch, considering that the correspondence shown in Table 1 is not perfect. One more result of consistency is shown in Fig. 1 (green full line) by considering only the 27 proxy stars. This result is not very different from the previous one, indicating the sufficiency of considering the proxy stars for further verification of the visibility condition for the nine seasonal boundary stars of *VGJ*. The internal consistency with minimum error exhibited by the 27 proxy and 83 constituent stars, when the winter solstice was in *śraviṣṭhā,* identified with β Del, upholds that the six equal division tropical zodiac was formalized in middle 2nd millennium BCE. This is still a broad picture, since seasonal dependence is inherent in the sequencing of the stars.

Several older Vedic texts mention the names of the six felt seasons and 12 months of the tropical year, implying that from the extreme southern declination day of sun the onset of the seasons was estimated in terms of multiples of 61 sun rises. The texts of Parāśara and Vṛddha-Garga exhibit more sophistication in that they connect the seasons with the position of sun with visible stars.

For declaring sun's position among the *nakṣatra*, which should have been useful in predicting the onset of a season in advance, careful observation of the morning and evening stars nearer to sun should have taken place over a prolonged period. Existence or otherwise of such an effort can be verified by considering the nine named asterisms *(2-rohiṇī, 3-mṛgaśira, 7-āśleṣā, 11-hasta, 12-citrā, 16-jyeṣṭhā, 20-śravaṇa, 21-śraviṣṭhā, 25-revatī)* as border points through which the transition from season to season was said to be taking place. This amounts to verification of coeval yearly visibility of the above nine specific *nakṣatra* in their respective divisions. This can be done by finding the error E_y for these nine stars separately. This result is also shown in Fig. 1 (green dot & dash line) where it is found that during 1210–1150 BCE the error of location of all the nine seasonal asterisms was precisely zero. There could be minor variations in the above result if small errors due to vague star boundaries are considered. Nevertheless, the core statement of *Ādityacāra* originating with the *śraviṣṭhādi (dhaniṣṭhādi)* scheme*,* cannot be more recent than 1150 BCE, from when the errors start steadily increasing.

At this stage one may question, due to the omission of *abhijit* from the original 28 Vedic *nakṣatra* system, whether our identification of the stars corresponding to *śravaṇānta* and *śraviṣṭhādi* for the start of the *śiśira* season needs a relook. How sensitive is our result for possible errors in identifying the Vedic *śraviṣṭhā* as β Del? Another question would be how sensitive are the results, if Abhyankar's list is used for checking the positional error.

6 *Abhijit, Śravaṇa, Śraviṣṭhā/Dhaniṣṭhā*

Vedic texts use the nomenclature *śraviṣṭhā* for the 21st *nakṣatra* and this is followed by *VGJ* in 13 out of 15 places. *Atharva Pariṣiṣṭa* knows only the name *śraviṣṭhā* which is cited 19 times. *Atharvaveda Saṃhitā* refers to *śraviṣṭāḥ* in the *Nakṣatrasūkta* and in the *Rātrisūkta*.[12] The nomenclature *dhaniṣṭhā* is found once in the *Bodhāyana Śrauta Sūtra* text. The Buddhist SKA, knows only *dhaniṣṭhā* mentioned 22 times. These are perhaps the BCE texts to use the name *dhaniṣṭhā* in the place of the older *śraviṣṭhā.* The *Mahābhārata* in one place uses the nomenclature

[12] *Atharva Veda Samhitā* (19.20 & 19.49.2).

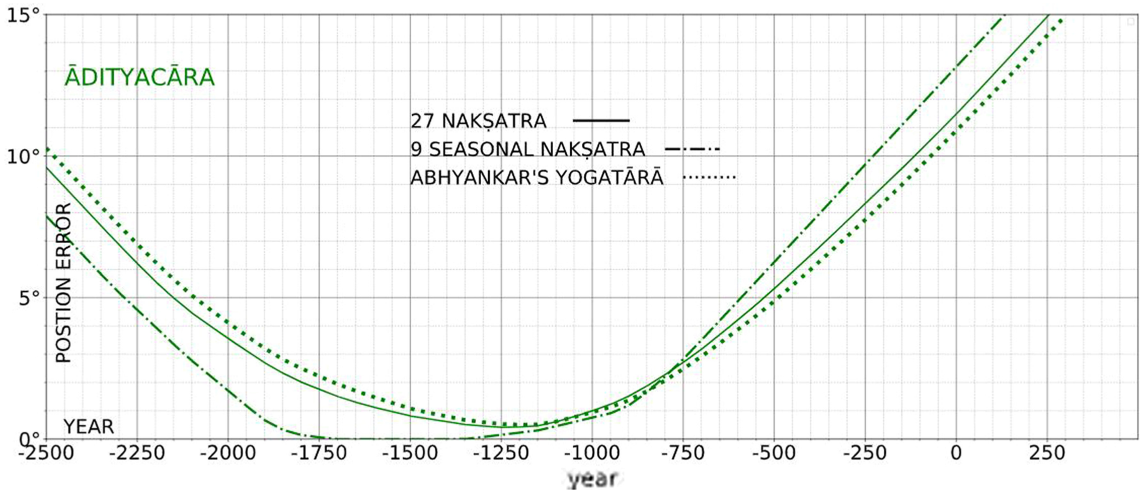

Fig. 2 Error sensitivity for possible identification of Vedic star *śraviṣṭhā* as β Aquari and *śravaṇa* as β Delphini. The readjusted 27 proxy stars and the *yogatāra*s of Abhyankar lead to almost the same result of *c* 1250 BCE for the error minimum. Errors for the nine seasonal *nakṣatra* boundaries remain zero during 1700–1350 BCE

śraviṣṭhā,[13] otherwise *dhaniṣṭhā* appears in four instances. The epic has the famous legend of *abhijit* going away to do penance when Time was made to begin with *dhaniṣṭhā* by Brahma.[14] This makes a case for arguing that, at some time in the past the winter solstice was occurring with sun in a *nakṣatra* part called *śraviṣṭhārdha* (*MAU*) and still later it fell back to the beginning parts called *śraviṣṭhādi* (*PT*, *VGJ*). With passage of time, winter solstice was observed to be shifting towards *abhijit.* This changed winter solstice *nakṣatra* was called *dhaniṣṭhā* sounding similar to *śraviṣṭhā* and for equalizing the length of each season to 61 days covering 4½ *nakṣatra*, *abhijit* was eliminated. This must have affected visual identification of three nearby asterisms since the name of the *nakṣatra* and the order could not be violated. Abhyankar's (1991) line of argument on misidentification by later authors of these three Vedic *nakṣatra*s is different, but the conclusions are same. He worked on this issue to demonstrate that there is good ground to show that the ancient *abhijit,* with cow-horn as the astrograph in SCP and a small sky sector allocated between *U. āṣāḍha* and *śravaṇa,* was what is now called Aquila. *Śravaṇa* with the astrograph resembling an *Ear* was in Vedic times the constellation Delphinius, but due to the elision of *abhijit*, *śravaṇa* got identified with the constellation Aquila with three stars. This argument leads one to infer that in the older 28-*nakṣatra* list, *śraviṣṭhā nakṣatra* with five constituent stars should have been in the Aquarius constellation. After the solar equal *nakṣatra* system came into vogue, *śraviṣṭhā* with a new name *dhaniṣṭhā* became the winter solstice *nakṣatra* visualized as α, or β Del. This line of argument postulates a transition period between the 28-*nakṣatra* cycle year and the 27-*nakṣatra* tropical year divided equally into six seasons. In such a transition period, *abhijit* was ignored when *śiśira ṛtu* started with sun in Aquarius and *śraviṣṭhā* approximately identifiable as β Aqr and *śravaṇa* as β Del. The reality or otherwise of this transition period can be verified by the same methods as discussed above.

The error E_y for the 27 asterisms and also for the nine seasonal stars with the above two readjustments is shown in Fig. 2. On the same figure the error variation of Abhyankar's 27- *yogatāra* list is superposed. It is observed that the overall error for the 27 asterisms, taken either as the proxy stars or as the *yogatāra* of Table 1, reaches its minimum still around 1250 BCE. But the interesting fact is that all the stated nine *nakṣatra* season boundaries would have remained visible in their respective longitudinal divisions within a year for a long period of 1700–1350 BCE. This indicates that the prose *PT* textual tradition of Parāśara which knew *abhijit* with three stars and also the *śraviṣṭhādi* scheme of 4½ *nakṣatra* per season must be more ancient than 1350 BCE. This helps us to surmise that the six-part zodiac stated in the *Parāśaratantra* starting with the *śisira-ṛtu* originated first in terms of day numbers counted from the winter solstice day. Thus, errors notwithstanding, the theoretical six division tropical zodiac was fully developed and in use by the Vedic schools of astronomy already by 1500 BCE. This stability got disturbed around 1300 BCE and observed to be so, when two new asterism identities but with old names, as discussed previously were introduced most likely by Vṛddha-Garga or his followers.

[13] अहः पूर्वं ततो रात्रिर्मासाः शुक्लादयः स्मृताः । श्रविष्ठादीनि ऋक्षाणि ऋतवः शिशिरादयः ॥ *MB Aśvamedhika parvan* (44.2).

[14] धनिष्ठादिस्तदा कालो ब्रह्मणा परिनिर्मितः । रोहिण्याद्योऽभवत्पूर्वमेवं सङ्ख्या समाभवत् ॥ *MB Vana parvan* (219.10).

Once again the seasons remained true with the original *nakṣatra* nomenclature during a short span of 1210–1150 BCE. But this order could not remain unchanged and had to be reorganized. How this was done is not clear. But *VGJ* which is like a compendium of the Vṛddha-Garga tradition takes us further in time by a few centuries to the monthly transit of sun through twelve *nakṣatra* in the *Ṛtusvabhāva* section.

7 Continuity of observations

The *Ādityacāra* chapter with 135 verses, as it is available now, can only be quoting the above seasonal transit of sun (v. 47, 48, 52–55) from some ancient text or tradition followed by the *VG* School. This follows easily, once we recognise that a later verse[15] (v. 125) in the same chapter mentions "*sun turning north without reaching the śraviṣṭhā asterism and not reaching āśleṣā on return is cause of fear*". This is clearly an observation of the effect of precession with passage of time and taken as a bad omen due to change of the *śraviṣṭhā* epoch. Such an observation seems to have happened towards the beginning of the 1st millennium BCE. This follows from the 59th section (*upāṅga*) of *VGJ* known as *Ṛtusvabhāvaḥ*. This section has six chapters, one each for the six seasons starting with the *vasanta*. All the chapters are a mix of prose and poetry. Interestingly in each chapter the *nakṣatra* through which sun transits in the 2 months of the season is stated along with the name of the month. Thus, here for the first time in Hindu astronomy we come across the 12-month solar zodiac, not in terms of the *Rāśi* signs (*meṣa, vṛṣabha* etc.*)*, but in terms of the names of months starting with the Vedic month *madhu* equated in civil calendar reckoning with *caitra*. The chapters have varying number of verses totalling seventy-five, increased further with archaic prose sections that describe the seasons qualitatively in terms of weather, flora, fauna and social behaviour. Here only the text of interest containing information on sun's transit is presented followed by a gist for further analysis.

वसन्तघर्मौ जलदागमश्च विद्याच्छरद्धैमतशैशिरौ च ।
ऋतून् पृथग्लक्षणतः प्रवक्ष्ये संवत्सरं ये परिवर्तयन्ति ॥
तेषामुदग्दक्षिणतश्च गच्छेद्यावान् विवस्वान् प्रचिनोति तावान् ।
तांस्तान् प्रवक्ष्यामि तथैव सर्वान्यथा च वै लौकिकवैदिकानि ॥
यद्रेवती ऋक्षमुपैति भानुश्चैत्रः स मासो मधुसंज्ञकश्च ।
वैशाखमासोऽपि च माधवश्च तदा हि भानुर्भरणीगतः स्यात् ॥
एतैर्वसन्तः समयैर्विदध्याद्द्वौ द्वौ च पक्षौ भवतीह मासः ।
(*VGJ Aṅga* 59; Ch.1)

I shall explain individually the character of the seasons; *vasanta, grīṣma, varṣa, śarat, hemanta, śiśira* that cyclically change the year. Also, I will explain, as sun goes from north and from south, his access to the civil and the Vedic months. When sun attains *revati* asterism, that month is *caitra* also known as *madhu*. *Vaiśākha* is also the *mādhava* month. Then sun would have reached *bharaṇi*. By this *vasanta ṛtu* is recognized and each month is made of two fortnights.

शुचिशुक्रौ मृगशिरो गच्छत्कुर्यात्तु भानुमान् ।
तथा पुनर्वसू चैव ज्यैष्ठाषाढौ तु तौ स्मृतौ ॥
एतौ मासौ विजानीयाद्ग्रैष्मिकौ कालवित्तमः ।
(*VGJ Aṅga* 59; Ch.2)

Sun in *mṛgaśiras* is the month *śuci* known also as *jyeṣṭha*. Sun in *punarvasū* is the *śukra* month same as *āṣāḍha*. These two months are to be known as the *grīṣma ṛtu.*

नभस्तु कुर्तयादुपसर्प्यमाणो रविर्मघाश्रावणजातसञ्ज्ञा ।
तत् प्रोष्ठदं च तथा नभस्यं गत्वा विदध्याद्भगदैवतर्क्षम् ॥
एतौ तु वार्षिकौ मासौ विद्यात्कालविशारदः ।
(*VGJ Aṅga* 59; Ch.3)

When sun approaches *maghā,* the month is *nabhaḥ* known as *śrāvaṇa*. Next, having gone to *pūrvaphalguni* sun makes the *nabhasya* month same as *bhādrapada*. These two are the rainy months (*vārṣikau māsau*).

इषुमाश्वयुजं विद्याद्भानुश्चित्रागतस्तदा ।
कार्तिकं जनयत्यूर्जमैन्द्राग्न्यं प्राप्यरश्मिवान् ॥
(*VGJ Aṅga* 59; Ch.4)

Month *iṣu* equivalently *āśvayuja* is when sun has reached the *citrā* asterism. Sun generates *kārtika* month also known as *ūrja* having reached the *viśākhe* asterism.

ऐन्द्रं समासाद्य तथोष्णरश्मिः स मार्गशीर्षं सहसं करोति ।
अब्दैवते त्वेव गतः सहस्यं पौषं विदध्यात् प्रचिनोति मासम् ॥
(*VGJ Aṅga* 59; Ch.5)

Sun in *jyeṣṭhā nakṣatra* makes the *mārgaśira* month same as *sahas*. When sun goes to *pūrvāṣāḍha*, it is the month of *pauṣa* or *sahasya.*

गतश्रविष्ठासमयं तु माघस्तपोविधत्ते भगवान् विवस्वान् ।
सफाल्गुनं चापि तथा तपस्यं पूर्वां गतप्रोष्ठपदां करोति ॥
ऋतुं तु विद्याच्छिशिरं विचार्य तस्यैव भावावयवं च सम्यक् ।
(*VGJ Aṅga* 59; Ch.6)

[15] यदा निवृत्तेदप्राप्तः श्रविष्ठामुत्तरायणे । आश्लेषां वा यदाऽप्राप्तस्तत्र विद्यान्महद्भयम् ॥ (v.125).

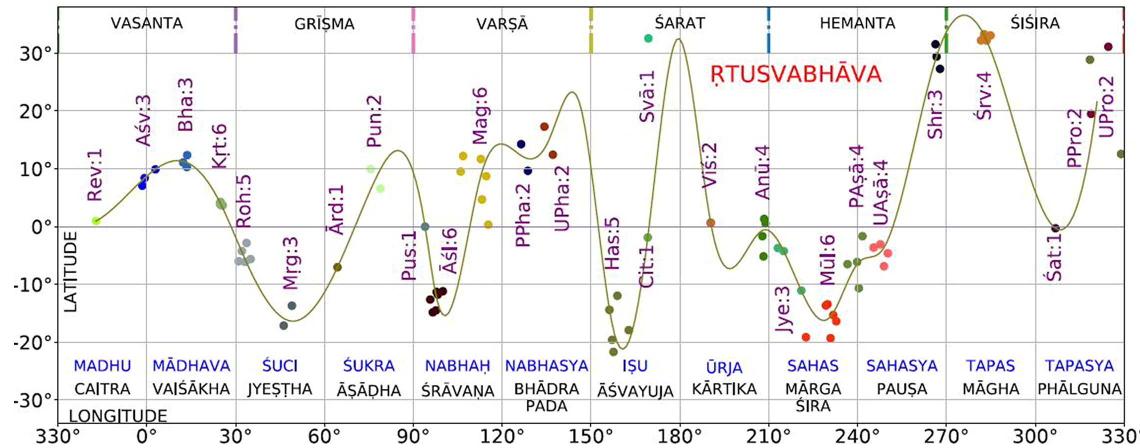

Fig. 3 Twelve month (*madhu-tapasya*) or (*caitra-phālguna*) Sun's transit in 500 BCE as per the *Ṛtusvabhāva* (59th *aṅga*) of *VGJ*

> The month of *māgha* or *tapas* is when the time for *śraviṣṭhā* is past. Sun makes the month *phālguna* or *tapasya* having attained the *pūrvābhādrā nakṣatra*. This should be understood as the *siśira ṛtu* with is parts and features.

The above solar transit is different from the previous one, not only in the star positions but more so in the way it is organized and stated. The description is still about the seasons, but here it begins with the *vasanta* (spring) and not the *śiśira* (winter). The older *ādityacāra* was only about the seasons with no mention of the months. Here the stress is on the months for which their Vedic and *laukika* (civil/popular) names are given. Seasons are mentioned only in terms of the months and not as per any *nakṣatra* boundaries. For each month starting from *madhu/caitra*, the prominent *nakṣatra* through which sun passes is mentioned. This way there are 12 months and correspondingly twelve *nakṣatra*, each spanning 30° in longitude. The equinox is here reckoned in the middle of the *vasanta ṛtu,* and the starting of the *mādhava/vaiśākha* month, with sun passing through the asterism *bharaṇi.* The implication is that this month started on the equinox day. The text does not name *aśvini* after *revatī*, through which sun had to transit before arriving at *bharaṇi*. Similarly, *kṛttikā, rohiṇī* are not mentioned before sun is said to be in the *mṛgaśiras nakṣatra* in the month *jyeṣṭhā.* The text is in line with the older tradition of reckoning the winter solstice as the start of the *śiśira ṛtu*. But, in the month of *māgha*, asterism *śraviṣṭhā* is mentioned not as with sun, but *having past its time*. The text just narrates the stars that were visible in the months that are named and counted starting from the vernal equinox or nearby full moon or new moon. This seems to be the origin of the solar calendar of twelve months, without any need for intercalation.

We can get an idea of the period in which the above 12-month solar zodiac was organized by finding the location error for the twenty-seven asterisms starting with the first named *bharaṇi* sector stretching from zero to 13° 20′ longitude as done previously. The result is shown in Fig. 1 (red lines) side by side with the results of the earlier seasonal zodiac. Clearly in the *VGJ* text there are two different observations of sun's position among the *nakṣatra*, separated by 700 to 800 years. One can further find an interval in which the twelve stated asterisms would have been visible in a given year in the specified months. This turns out to be (620–160) BCE. Since the text is silent on the visibility of adjacent *nakṣatra* in the named months, the above interval cannot be further refined. However, beyond reasonable doubt, we can say that the observational data available in the *Ṛtusvabhāva* section of *VGJ* belongs to the epoch of 600–500 BCE. As a demonstration of this, for the year 500 BCE the ecliptic coordinates of the eighty-three stars making up the twenty-seven *nakṣatra* are plotted in Fig. 3. The points are joined smoothly for better visualization with markings for the seasons and the months. It can be verified that all the twelve *nakṣatra* named in the *VGJ* text would have been visible sometime in the specified months.

8 Discussion

In popular parlance *nakṣatras* are taken as twenty-seven stars with which moon comes in contact. However, since Vedic antiquity several *nakṣatra*s are composed of multiple stars. All the five ancient texts shown in Table 1 state the number of stars for each of the *nakṣatra,* obviously due to some special importance attached to that number. We guess by hindsight, that multiple stars might have helped the ancient observers to follow the wavy path of moon, by recognizing some of the *nakṣatra* to have more than one star, for clarity in visual perception and memory. This was before *aṁśa* (1/4) and *ardha* (1/2) *nakṣatra* parts as in *MAU* came into vogue among particular groups of sky observers. *VGJ* in its chapters on the transit of moon postulates the conjunction of moon with a *nakṣatra* as being of three types; leading, following and at same level. It also states three groups of *nakṣatra* with which moon spends 15, 30 or 45 *muhūrta* of time in its sidereal month cycle of about 27 1/3 days. Such an observational model directly leads to vague spatial domains and unequal longitudinal intervals for the visible asterisms. Investigation of the unequal *nakṣatra* system is beyond the scope of the present paper, but it suffices to point out that the sequence of 28 *nakṣatra* with augmented star counts as background points for observing and remembering moon's spatial position should have existed from very ancient times. Gradually associating *nakṣatra* with sun arose once the seasons were differentiated, named and recognized as six in a year. The *nakṣatrasūkta* of the *Atharvaveda* (19.7) hints that one of the two north–south-north transit of sun happened in the asterism *maghā*.[16] This must have been the southern sojourn (*dakṣiṇāyana*) of sun when some stars of the *maghā* asterism such as α, η-Leo were at around 90° longitude. The *Yajurvedic MAU* specifically differentiates the felt weather for sun's north to south transit from *maghā* to *half-śraviṣṭhā* for 6 months as *hot* and the 6 month return from south to north as *mild*. Starting with such formulations in the Vedas proper, astronomy emerged as an ancillary to the Vedas by the middle of the second millennium BCE, to be aptly called *Vedāṅga Jyotiṣa*.

Three textual traditions of *Jyotiṣa* attributed to Parāśara, Vṛddha-Garga and Lagadha, have come down to us from this period. Among these three, the first called the *Parāśaratantra* (*PT*) being largely in prose stands in stark contrast with the other two. This is the first text to give the six seasonal solar zodiac; conditions for the rise and set of the southern star Agastya (Canopus); visibility day numbers for Venus, Mercury, Jupiter, and Saturn. This is also the first text to list twenty-six comets with names, their transit among the stars and arrival intervals in years. The second text denoted here as *VGJ* contains archaic prose parts and also long versified chapters on varied topics added at later dates. The text seems to have had an original nucleus in the 24th section named the *Mahāsalilaṁ* over which later layers have been deposited in differing order. It is plausible that *PT* and *VGJ* originated as independent traditions, but over time *VGJ* seems to have inherited the astral content of the *Ādityacāra,* some parts of *Rāhucāra* and large parts of *Ketucāra* from *PT*. *VGJ* is more detailed about moon, the sidereal and synodic months and the unequal time spent by moon with the asterisms. Both the texts present matter-of-fact sky observations. *VGJ* is more detailed, repetitive and with texts of several other authors interpolated by the manuscript copyists. While *PT* is purely observational, *VGJ* recommends combination of observation and computation in the context of moon's conjunction with the stars.[17] *VGJ* has long chapters devoted to each of the five planets, with quantitative information on visibility and retrograde movement of Mars, which is absent in *PT*. Lagadha's work on finding the position of sun and moon in the 5-year cycle is short and terse but more sophisticated than the other two being entirely computational. The common factor of all the three is their Vedic origin, absence of week days and *Rāśi* (Sign) notation and starting of the yearly cycle at the winter solstice point, even if the determination of this were to be approximate. If we take the general view that sky observations precede computational approaches, the chronological order of the three *Vedāṅga Jyotiṣa* tradition has to be first *PT*, next *VGJ*, followed by the *Ārca-yājuṣa-jyotiṣa* of Lagadha. All the three have Vedic precedents as well as later interpolations, but interestingly in *VGJ* we get a verifiable temporal separation of eight centuries (*c*1300 to 500 BCE) between two chapters on the transit of sun through the *nakṣatra* circle.

9 Conclusion

The *nakṣatra* system for tracking moon in the background of stars has been in vogue since very ancient times. As interest in understanding the relation between seasons and the position of sun grew, identifying some special *nakṣatra* for heralding important seasons came into practice. Naked eye observation of rise of sun in the extreme south position of the horizon was the starting of the *śiśira ṛtu*, harmonized as the winter solstice day. Probably in the early days when observation of sun's position with a *nakṣatra* was not yet practiced, the onset of the seasons was counted in number of days starting from the vague winter solstice day. With evidence for observing early morning Vedic *nakṣatra* before sunrise as in the *Taittirīya Brāhmaṇa* and the northern and southern sojourn of sun correlated with visible *nakṣatra*s as in *MAU,* we can say that a primitive solar zodiac was theoretically conceptualized in the core Vedic period with two *ayana*, three *cāturmāsya* and six *ṛtu* (seasons). This background work got empirically formalized in *PT* and *VGJ* by observing the seasonal boundary *nakṣatra*s in the early morning sky, by which the onset of the seasons could be forecast. Such seasonal *nakṣatra* information available in *VGJ*, in two different sections, is analyzed in the present study. Sun's transit through the six seasons mentioned in terms of nine *nakṣatra* names forms part of the earlier

[16] पुनर्वसू सूनृता चारु पुष्यो भानुराश्लेषा अयनं मघा मे || (*Atharva Veda Saṁhitā* 19.7.2b).

[17] नहि सर्वत्र गणितं नहि सर्वत्र दर्शनम् । दर्शनं गणितं चैव युगपद्योगसाधकम् || (*VGJ*; *Aṅga* 2; *Candramārga*, v.6).

Ādityacāra section. This can be shown to belong to *c* 1300 BCE. The *Ṛtusvabhāva* section wherein prominent twelve *nakṣatra*s through which sun transits in the 12 months of the year are stated can be dated to *c* 500 BCE. This by itself should be of interest in following how the original Vṛddha-Garga school has contributed to the development of astral literature in India before the Common Era.

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