Precession of Equinoxes and Sun's Transit in the Vṛddha-Gārgīya Jyotiṣa

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ज्योतिःशास्त्रम् (Astral Science)

- Starts with observations of - sun, moon and the planets- in the background of stars
- Progresses - from broad observations to finer observations of positions and movements
- Further progresses towards a computational model

वृद्धगार्गीयज्योतिषम् (VGJ)

- Big text ~5000 verses and some prose, 24 *aṅga-s*, 40 *upaṅga-s*
- CAHC has published a critical edition of 7 chapters from the 1st and 2nd *aṅga*

Focus of this talk - two Sun Transit chapters of VGJ

1. **आदित्यचारः 11th section**
2. **ऋतुस्वभावः 59th section, chapters 1-6**

Sun's Annual Swing

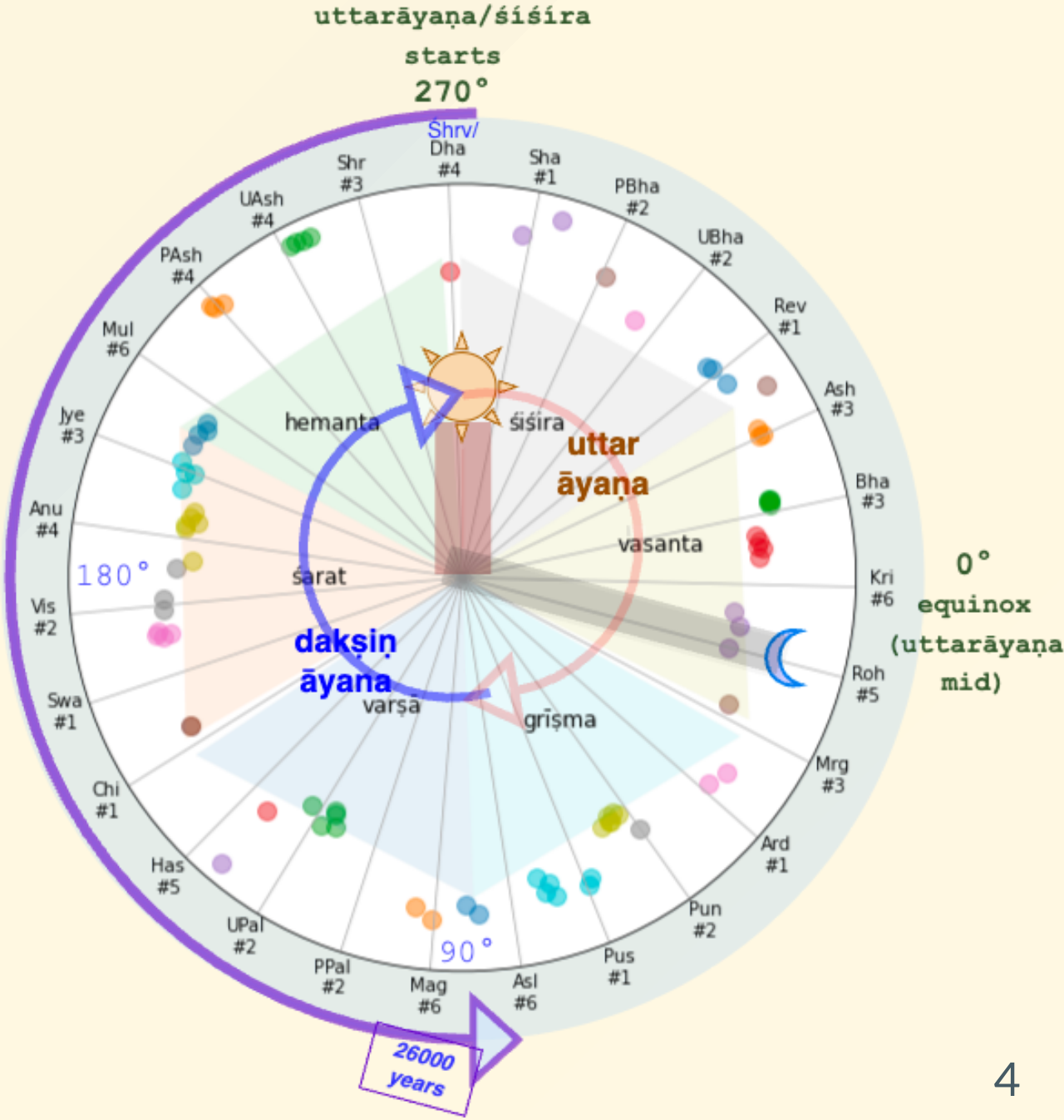
- An observer watching every sun rise through the year will see this swing

	uttarāyaṇa start (winter solstice)	vernal equinox	dakṣiṇāyana (summer solstice)	autumn equinox
sun's longitude	270°	0°	90°	180°

- In one year, the Sun makes
  - one ***uttarāyaṇa*** (south-to-north) and one **dakṣiṇāyana** (north-to-south) swing
  - the extreme points are **solstices**, *winter* and *summer* respectively
  - **equinox** is the mid point of these swings - *vernal* and *autumn* equinoxes

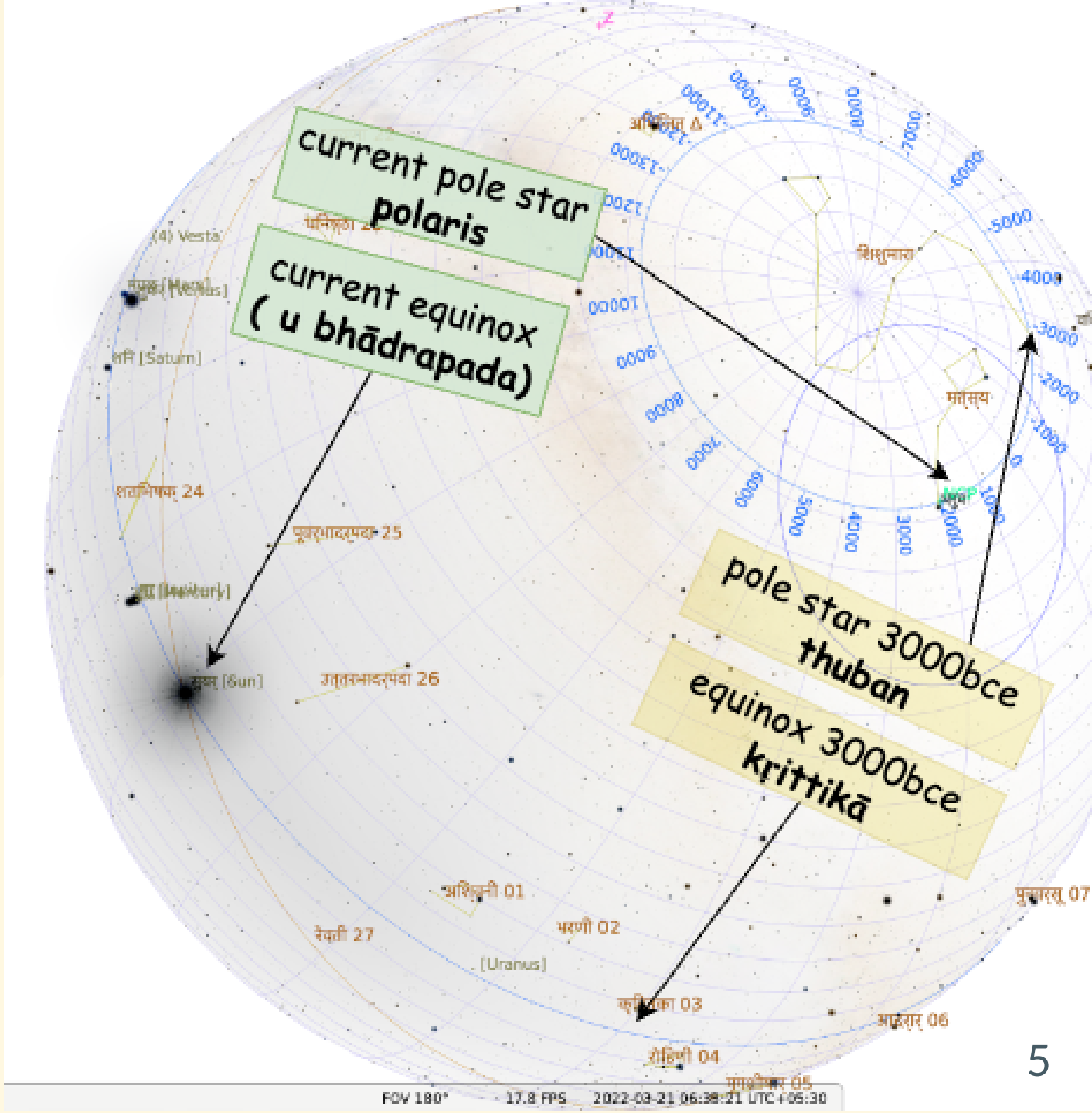
Nakṣatra-s

- **Nakṣatra-s** are zones/stars on the ecliptic belt in the sky through which Moon, Sun and planets travel. They contain one or constituent stars
- Using clock analogy
  - Nakṣatra-s are the dial markings - 27(28)in all
  - The quicker hand is the Moon - one round a sidereal month
  - The slower hand is the Sun - one round a sidereal year .
- Stars of some *nakṣatra-s* are unambiguously identified
  - कृत्तिका, रोहिणी, मघा, हस्ता, चित्रा,स्वाति, विशाखे, ज्येष्ठा, मूला
- Others have some ambiguity
  - आर्द्रा, श्रविष्ठा/धनिष्ठा, रेवती
- These sources help identify stars of *nakṣatra-s*
  - Gondalekhar(2013), Abhyankar(1991), Saha and Lahiri(1955), PT, VGJ, ...

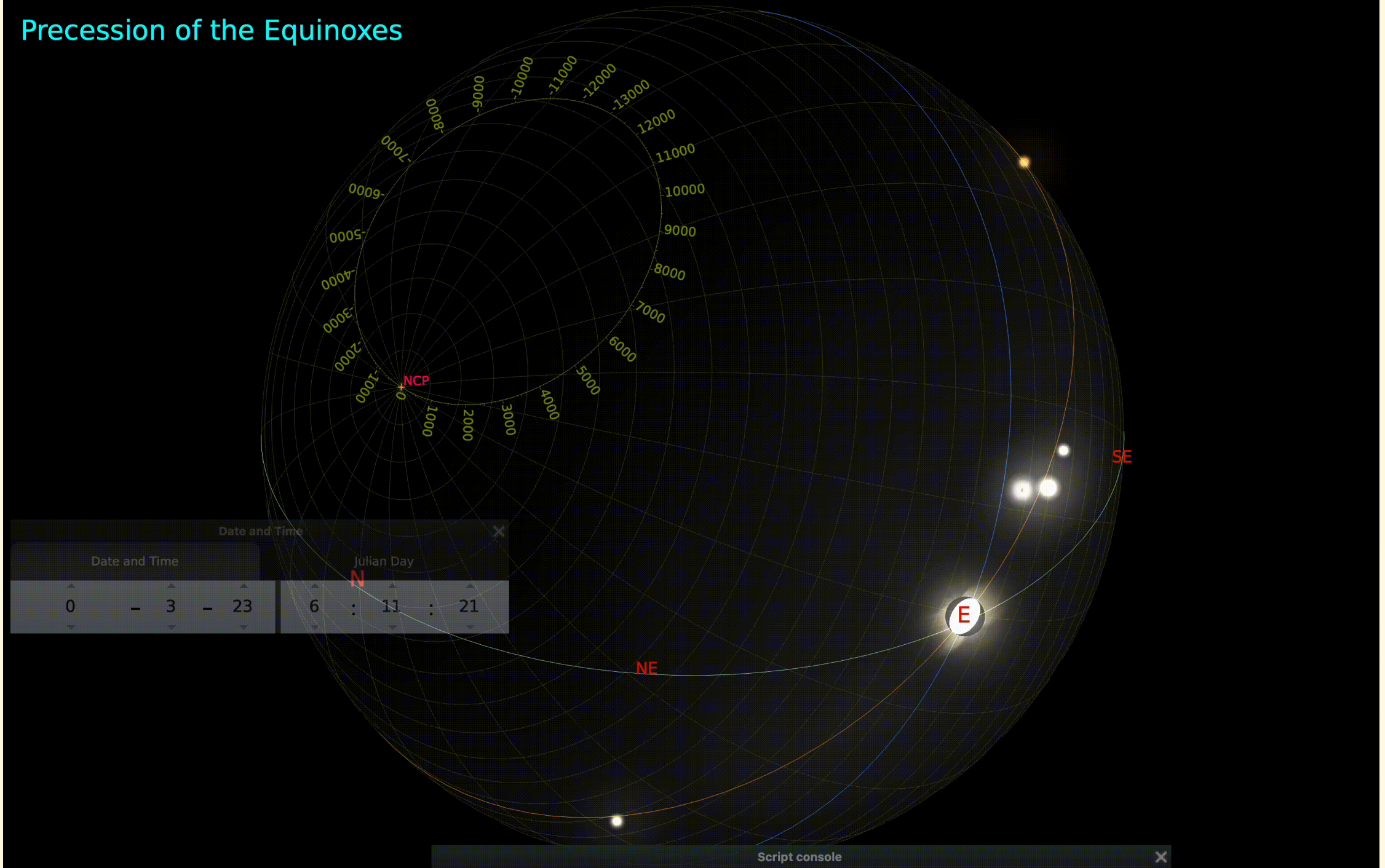


Precession of the equinoxes

- **Precession** has the following effects
  - The *nakṣatra* marking the seasons/equinoxes **move by 1 *nakṣatra* every ~1000 years**
  - The **pole star has drifted** from *abhayadhruva* (thuban) around 3000 BCE to around *dhruva* (polaris) now
- It is caused by wobble of the earth's axis much like wobble of a spinning top.
- In the clock analogy precession is rotation of the season dial
  - In direction opposite to Sun/Moon hand
  - And takes ~26000 years to complete a round
- Is an important phenomena to date astronomical observations
  - In our approach we precess mutiple stars to date observations to minimize errors



Precession of the Equinoxes



Nakṣatra Listings

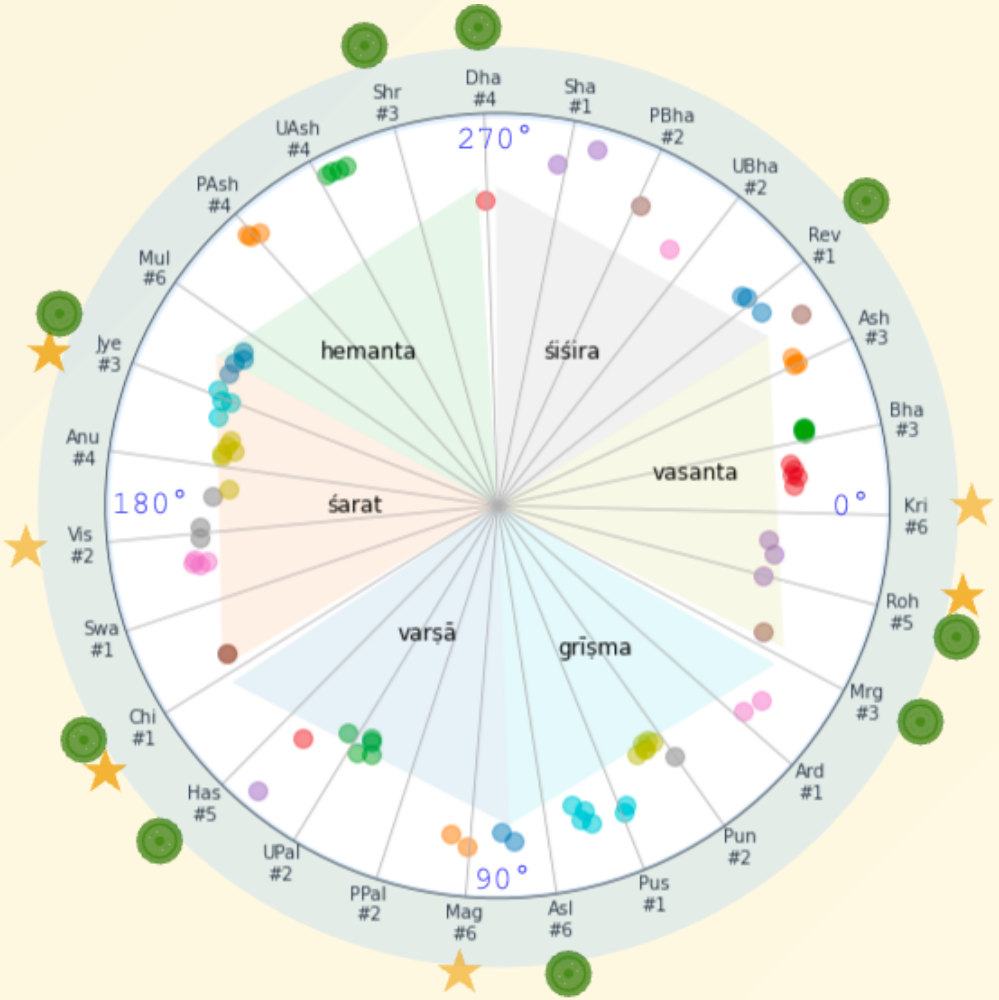
- The table shows **83 constituent stars** of the *nakṣatra-s* per VGJ
- Vedic, Jaina & Baudha texts have **astrograph and count** information
- **Proxy stars** for each *nakṣatra*, help model the **ādi, ardha, anta** (begin, mid, end) in the text
- A few astrographs

#	Nakṣatra	Star Count					Astrograph	Constituent Stars	Proxy Star (Author's)	Abhyankar's Yogatara
		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	Bāhuḥ (Arm) Red Dot*	(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	Hasta (hand)	(α,β,γ,δ,ε) Crv	δ Crv	γ Crv
12	Citrā	1	1	1	1	1	Madhupuṣpa (Flower)*	(α) Vir	α Vir	α Vir
13	Svātī	1	1	1	1	1	Kīlaka (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,(τ)) 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	Simhaniṣadya (Lion seat)*	(ζ,σ,τ,φ) Sgr	τ Sgr	σ Sgr
**	Abhijit	-	3	1	3	3	Gośīrṣāvali*	(?) Vega	-	α Aql
20	Śravaṇa	3	3	3	3	3	Ear Yavamadhya (Barleyseed)1	(α,β,γ) Aql	α Aql	β Del
21	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 Proṣṭapada	2	2	2	2	2	Cow's Foot	(α,β) Peg	α Peg	α Peg
24	U Proṣṭapada	2	2	2	2	2	Cow's Foot	(γ) Peg (α)And	γ Peg	γ Peg
25	Revatī	1	1	1	1	32	Boat*	(ε,(α,ζ)) Psc	ε Psc	ζ Psc (α And)
26	Aśvayuk	3	2	1	2	3	Horseneck	(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
		83	82	78	82	222				

आदित्यचारः (*Sun's transit*)

Verse	From	To	Ṛtu	Span
श्रविष्ठादीनि चत्वारि ***पौष्णार्धञ्च*** दिवाकरः । वर्धयन् सरसस्तिक्तं मासौ तपति **शैशिरे** ॥ 47	श्रविष्ठा begin	रेवती mid	शिशिर	270°-330°
रोहिण्यन्तानि विचरन् *पौष्णार्धाद्याच्च* भानुमान् । मासौ तपति **वासन्तौ** कषायं वर्धयन् रसम्॥ 48	रेवती mid	रोहिणी end	वसन्त	330°-30°
सार्पार्धान्तानि विचरन् *सौम्याद्यानि* तु भानुमान् । **ग्रैष्मिकौ** तपते मासौ कटुकं वर्धयन् रसम्॥ 52	मृगशिरा begin	आश्लेषा mid	ग्रीष्म	30°-90°
सावित्रान्तानि विचरन् *सार्पार्धाद्यानि* भास्करः । **वार्षिकौ** तपते मासौ रसमम्लं विवर्धयन्॥ 53	आश्लेषा mid	हस्ता end	वर्षा	90°-150°
चित्रादीन्यथ चत्वारि ***ज्येष्ठार्धञ्च*** दिवाकरः। **शारदौ** लवणाख्यं च तपत्याप्याययन् रसम्॥ 54	चित्रा begin	ज्येष्ठा mid	शरद्	150°-210°
ज्येष्ठार्धादीनि चत्वारि ***वैष्णवान्तानि*** भास्करः । **हेमन्ते** तपते मासौ मधुरं वर्धयन् रसम् ॥ 55	ज्येष्ठा mid	श्रवण end	हेमन्त	210°-270°

- Similar information is found in the PT as prose
  - Maps each of 6 ṛtu to a span 4½ *nakṣatra* (of 61 days)
  - **PT book** dates *6 bright stars(★)* to **1350-1130 BCE**, based on visibility in their stated seasons
- An **improved dating** fits below for their stated seasons
  - *9 circled seasonals(🟢) nakṣatra-s*
    27 proxy stars
    83 constituent stars
  - This yields **50 years around 1250 BCE** - a finer window



Finding Epoch Using	★ *6 bright stars*	*1350–1130 BCE*
	🟢 9 seasonals nakṣatra-s 27 proxy stars 83 constituent stars	*50 years around 1250 BCE*

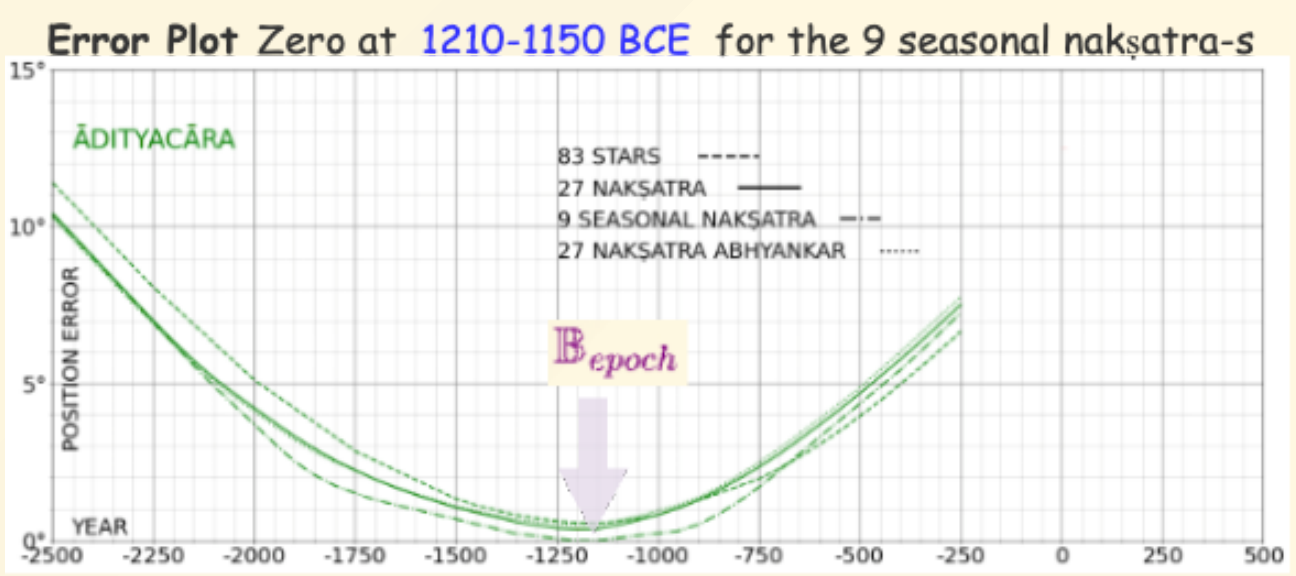
आदित्यचारः - date estimation

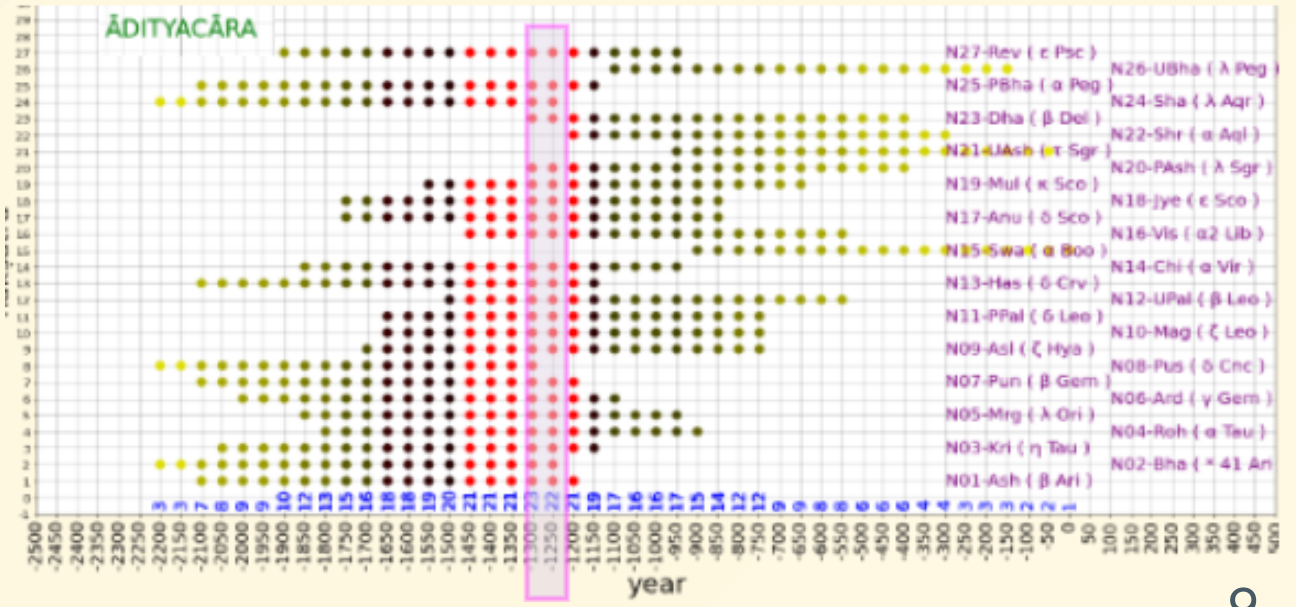
- From the text
  - *nakṣatra-s* are equally spaced at 13.33° - given seasons are of equal of 4½ *nakṣatra-s*
  - शिशिर start is sun with श्रविष्ठादि taken as 270°
  - Given the *nakṣatra-s* sequence and above, span of each *nakṣatra* is obtained
- The **best fit method** finds the epoch where most stars of *nakṣatra-s* are in their prescribed span
  - Get longitude of 83 stars from -2500 to 500 in 50 year epoch steps
  - For each epoch compute this error metric $\mathbb{E}_{epoch}$
  - The epoch with **lowest error metric** is the best fit $\mathbb{B}_{epoch}$

$$\mathbb{B}_{epoch} = \underset{epoch \in -2500,500,50}{\arg\min} \mathbb{E}_{epoch}$$

$$\mathbb{E}_{epoch} = \frac{1}{27}\sum_{\mathcal{T}=1}^{27} \frac{\sum_{\bar{\mathcal{T}}=1}^{T_{\mathcal{T}}} err_{\mathcal{T},\bar{\mathcal{T}}}}{T_{\mathcal{T}}}$$

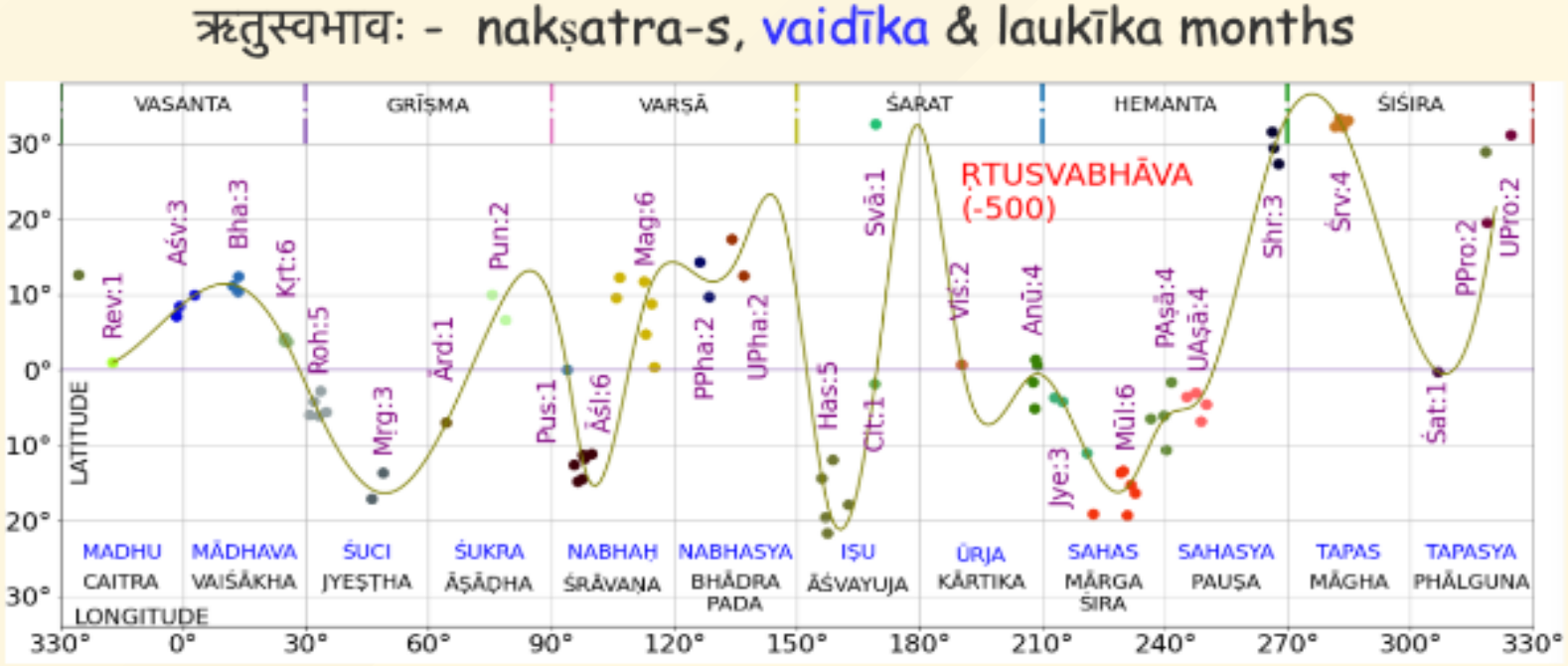
$$err_{\mathcal{T},\bar{\mathcal{T}}} = \begin{cases} 0, & \text{if } long_{\mathcal{T}} < long_{\bar{\mathcal{T}}} < long_{\mathcal{T}+1} \\ else & min(\left|long_{\bar{\mathcal{T}}} - long_{\mathcal{T}}\right|, \left|long_{\bar{\mathcal{T}}} - long_{\mathcal{T}+1}\right|) \end{cases}$$

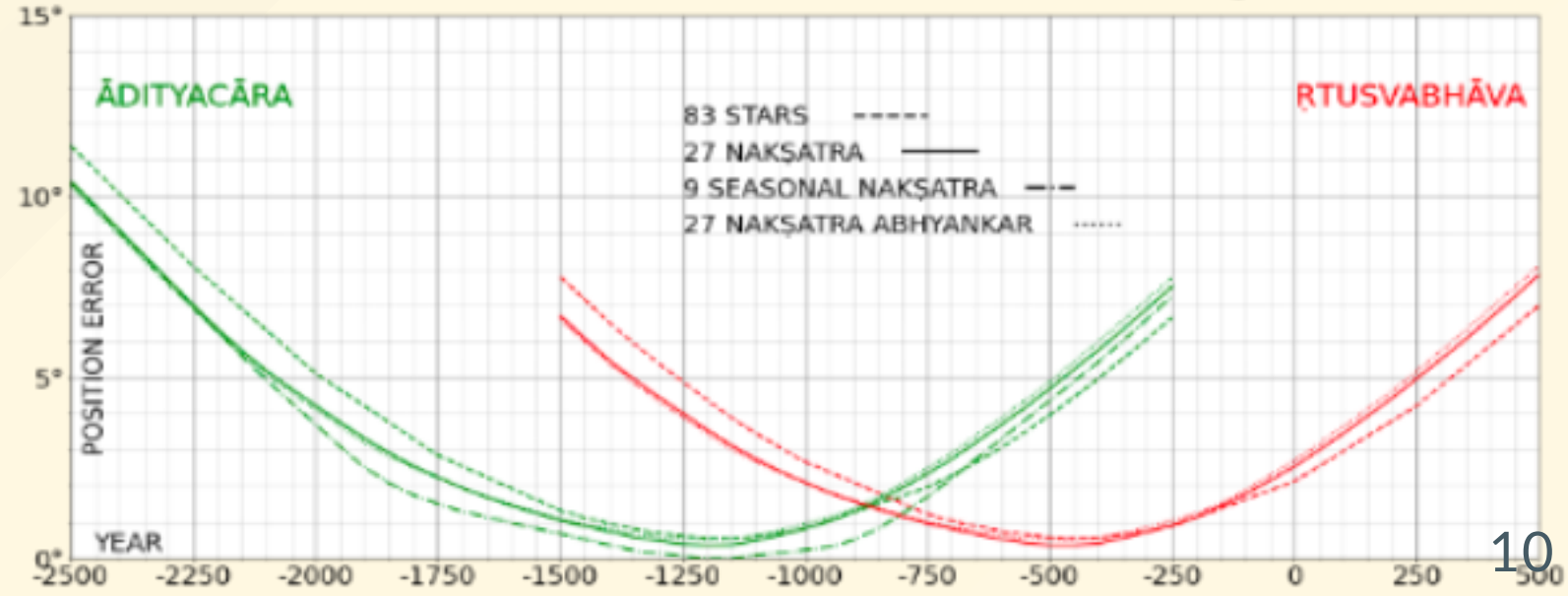




ऋतुस्वभावः

- Describes Sun's path through
  - 12 *vaidika* and equivalent *laukika* months and 12 *nakṣatra-s* for each of these months - ~30° apart
  - 6 seasons and their months
- This is different from आदित्यचारः
  - Ṛtu sequence begins with वसन्त not शिशिर
  - Ṛtu are related to months, not *nakṣatra* span & boundaries
  - श्रविष्ठा is past its time when शिशिर starts, not heralding शिशिर
  - A 12 month **solar zodiac**, obviating intercalation, emerges





In closing

- **2 Ayana/6 Ṛtu** based sun transit conceptualized earlier - ~ 1700 BCE
- **VGJ/आदित्यचारः** observations date to ~*1250 BCE* with *4½ nakṣatra-s* span per season
- **VGJ/ऋतुस्वभावः** observations date to ~*500 BCE* with *12 solar months*
- **VGJ is layered** and contains information across generations of observations and inferences
- **Solar zodiac** is certainly part of original Indian knowledge - that has been recorded and evolved over time

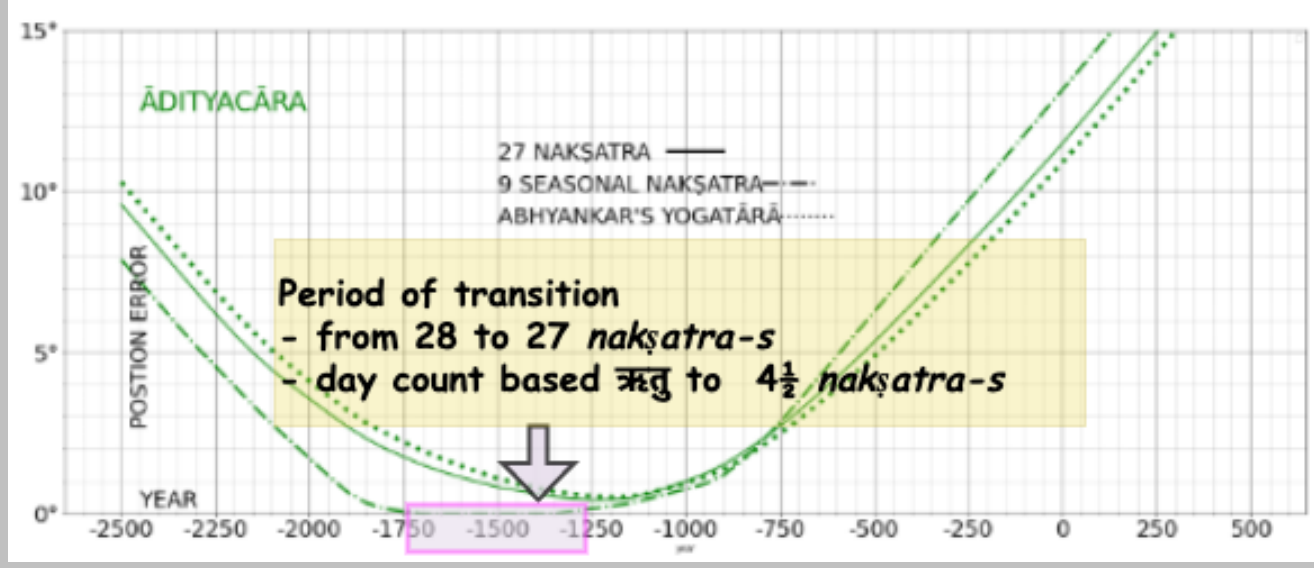
From Observations to Computations

Vedic	अथर्ववेद परिशिष्ट	*Atharvaveda-pariśiṣṭa (AVP)*
Vedāṅga	पराशरतन्त्रम्	*Parāśara Tantram(PT)*
	व्रद्धगार्गीय ज्योतिषम्	*Vṛddhagārgīyā Jyotiṣam (VGJ)*
	लागधीय वेदाङ्गज्योतिषम्	*Lagadhiyā Vedāṅga Jyotiṣam (LVJ)*
Jain	सूर्य चन्द्र प्रज्ञप्ति	*Sūrya-candra-prajñapti (SCP)*
Baudha	शार्दूलकर्णावदान	*Śardūlakarṇāvadāna (SKA)*
Siddhānta	आर्यभटीयम्	*Āryabhaṭīyam(AB)*

Transition from 28 to 27 *nakṣatra-s* *(अभिजित् , श्रवण, धनिष्ठा/श्रविष्ठा)*

- Winter solstice drift can be seen
  - श्रविष्ठार्धा in Maitrayani Aranyaka Upanishad to
  - श्रविष्ठादि in PT/VGJ
- At some point in the transition period
  - धनिष्ठा is named the winter solstice *nakṣatra*
  - अभिजित् is eliminated to pack 6 ṛtu of 4½ *nakṣatra-s*
  - 27 *nakṣatra-s* equal regime takes hold for the sun
  - 28 *nakṣatra-s* unequal regime stays for the moon
- Validating the transition period with
  - श्रविष्ठा as β Aqr, श्रवण as β Del(श्रवण/धनिष्ठा post transition) per **Abhyankar**
  - the 9 seasonal *nakṣatra-s* remain in bound from 1700-1350bce
- The 6 solar ṛtu system
  - started ~1700 BCE with day counts and per ṛtu
  - stabilized ~1300 BCE with 4½ *nakṣatra-s* per ṛtu

#	Nakṣatra	Star Count VGJ	PT	AVP	SKA	SCP*	Astrograph	Constituent Stars	Proxy Star (Author's)	Abhyankar's Yogatara
19	U Aṣāḍhā	4	4	4	4	4	Simhanişadya (Lion seat)*	(ζ,σ,τ,φ) Sgr	τ Sgr	σ Sgr
**	Abhijit	-	3	1	3	3	Gośīrṣāvali*	(?) Vega	–	α Aql
20	Śravaṇa	3	3	3	3	3	Ear Yavamadhya (Barleyseed)1	(α,β,γ) Aql	α Aql	β Del
21	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 Proṣṭapada	2	2	2	2	2	Cow's Foot	(α,β) Peg	α Peg	α Peg



4.4.10 अनुवाक 10 नक्षत्रेष्टका:

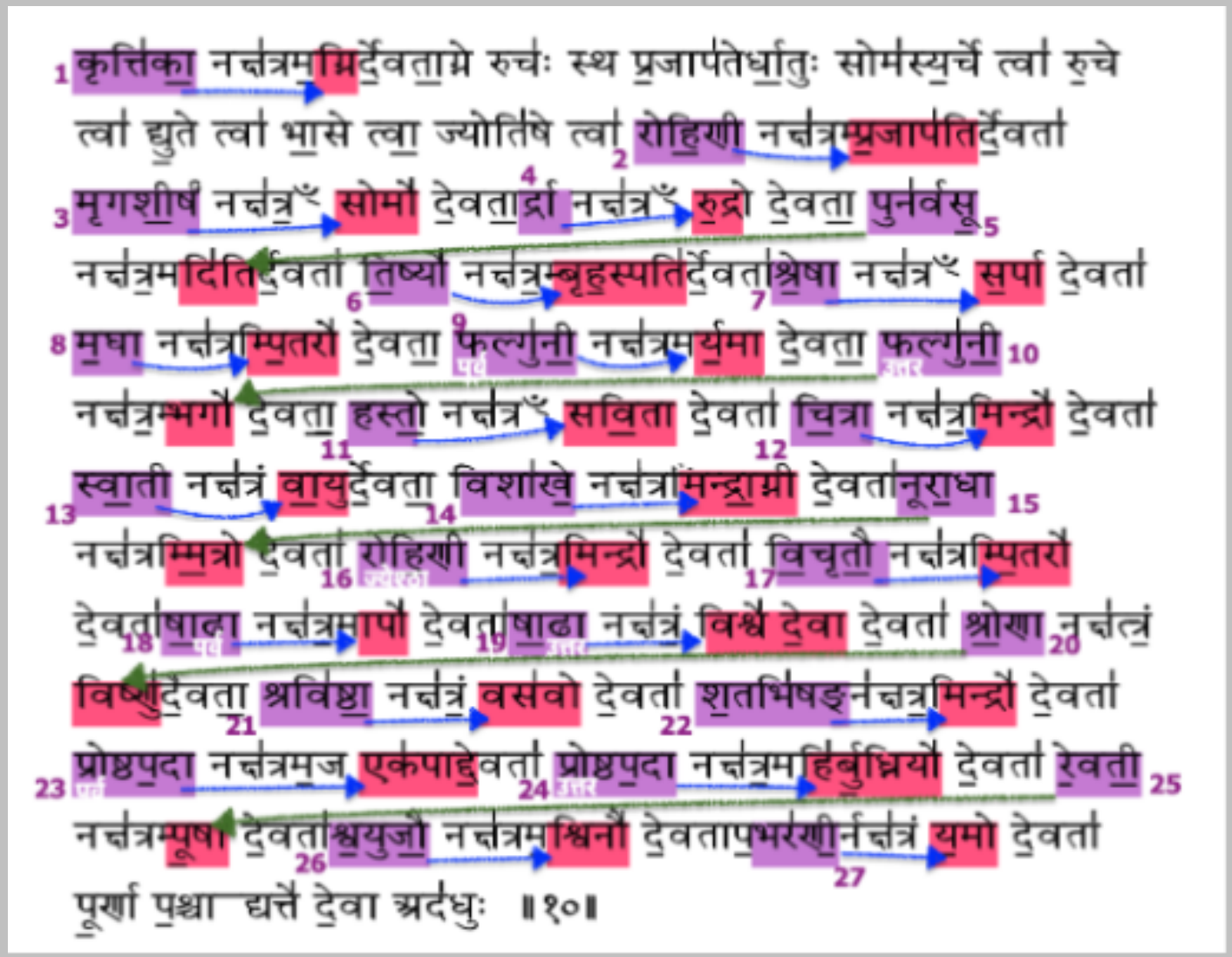
कृत्तिका नक्षत्रमग्निर्देवताऽग्ने रुचः स्थ प्रजापतेर्धातुः सोमस्यर्चे त्वा रुचे त्वा द्युते त्वा भासे त्वा ज्योतिषे त्वा
रोहिणी नक्षत्रम् प्रजापतिर्देवता मृगशीर्षं नक्षत्रं सोमो देवताऽऽर्द्रा नक्षत्रं रुद्रो देवता पुनर्वसू नक्षत्रमदितिर्देवता तिष्यो नक्षत्रम् बृहस्पतिर्देवताऽऽश्रेषा नक्षत्रं सर्पा देवता मघा नक्षत्रम् पितरो देवता फल्गुनी नक्षत्रम्

अर्यमा देवता फल्गुनी नक्षत्रम् भगो देवता हस्तो नक्षत्रं सविता देवता चित्रा नक्षत्रमिन्द्रो देवता स्वाती नक्षत्रं वायुर्देवता विशाखे नक्षत्रमिन्द्राग्नी देवता अनूराधा नक्षत्रम् मित्रो देवता रोहिणी नक्षत्रमिन्द्रो देवता विचृतौ नक्षत्रम् पितरो देवताऽषाढा नक्षत्रमापो देवताऽषाढा नक्षत्रं विश्वे देवा देवता श्रोणा नक्षत्रं विष्णुर्देवता श्रविष्ठा नक्षत्रं वसवो

देवता शतभिषङ् नक्षत्रमिन्द्रो देवता प्रोष्ठपदा नक्षत्रमज एकपाद् देवता प्रोष्ठपदा नक्षत्रमहिर् बुध्नियो देवता रेवती नक्षत्रम् पूषा देवताऽश्वयुजौ नक्षत्रमश्विनौ देवताऽपभरणीर्नक्षत्रं यमो देवता
पूर्णा पश्चाद्यत्ते देवा अदधुः ॥

4.4.11 अनुवाक 11 ऋतव्या इष्टका:

मधुश्च माधवश्च वासन्तिकाव् ऋतू
शुक्रश्च शुचिश्च ग्रीष्माव् ऋतू
नभश्च नभस्यश्च वार्षिकाव् ऋतू
इषश्चोर्जश्च शारदाव् ऋतू
सहश्च सहस्यश्च हैमन्तिकाव् ऋतू
तपश्च तपस्यश्च शैशिराव् ऋतू
अग्नेरन्तःश्लेषोऽसि कल्पेतां द्यावापृथिवी कल्पन्तामाप ओषधीः
कल्पन्तामग्नयः पृथङ् मम ज्यैष्ठ्याय सव्रताः



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Fitting Stars to Nakshatras

Diff of Nakṣatra-s list

Nakṣatra	PAPER-ABHYANK (1991) ConstituentStars	PAPER-ABHYANK (1991) YogaTara	PT-VGJ-RNI ConstituentStar	PT-VGJ-RNI ProxyStar	REPORT-SAHA-LAHIRI (1955) ConstituentStars	REPORT-SAHA-LAHIRI (1955) YogaTara
1 Kṛttikā	(17,19,20,23,27,η) Tau	η Tau	(17,19,20,23,27,η) Tau	η Tau	(17,19,20,23,27,η) Tau	η Tau
2 Rohiṇī	(α,γ,δ,ε,θ) Tau	α Tau	(α,γ,δ1,ε,θ2) Tau	α Tau	(α,γ,δ,ε,θ) Tau	α Tau
3 Mṛgaśira	(λ,θ1,θ2) Ori	λ Ori	(α,γ,λ) Ori	λ Ori	(λ,θ1,θ2) Ori	λ Ori
4 Ārdrā	(α) Ori	γ Gem	(γ) Gem	γ Gem	(α) Ori	α Ori
5 Punarvasu	(α,β) Gem (α,β) CMi	β Gem	(α,β) Gem	β Gem	(α,β) Gem	β Gem
6 Puṣya	(γ,δ,θ) Cnc	δ Cnc	(δ) Cnc	δ Cnc	(γ,δ,θ) Cnc	δ Cnc
7 Āśleṣā	(δ,ε,ζ,η,θ,σ) Hya	ζ Hya	(δ,ε,ζ,η,ρ,σ) Hya	ζ Hya	(δ,ε,ζ,η,ρ,σ) Hya	α Cnc
8 Maghā	(α,γ,ε,ρ,η,μ) Leo	α Leo	(α,γ1,ε,ζ,η,μ) Leo	ζ Leo	(α,γ,ε,ζ,η,μ) Leo	α Leo
9 P Phalgunī	(δ,θ) Leo	δ Leo	(δ,θ) Leo	δ Leo	(δ,θ) Leo	δ Leo
10 U Phalgunī	(93,β) Leo	β Leo	(93,β) Leo	β Leo	(93,β) Leo	β Leo
11 Hasta	(α,β,γ,δ,ε) Crv	γ Crv	(α,β,γ,δ,ε) Crv	δ Crv	(α,β,γ,δ,ε) Crv	δ Crv
12 Citrā	(α) Vir	α Vir	(α) Vir	α Vir	(α) Vir	α Vir
13 Svātī	(α) Boo	α Boo	(α) Boo	α Boo	(α) Boo	α Boo
14 Viśākhā	(α,β) Lib	α Lib	(α1,α2) Lib	α1 Lib	(α,β,θ,γ) Lib	α Lib
15 Anūrādhā	(β1,δ,π) Sco	δ Sco	(β1,δ,π,ω1) Sco	δ Sco	(β1,δ,π) Sco	δ Sco
16 Jyeṣṭhā	(α,σ,τ) Sco	α Sco	(α,ε,σ,(τ)) Sco	ε Sco	(α,σ,τ) Sco	α Sco
17 Mūla	(λ,ζ2,θ,ι1,κ,η,μ,ξ) Sco	λ Sco	(λ,ν,ζ2,θ,ι1,κ) Sco	κ Sco	(λ,ν) Sco	λ Sco
18 P Aṣāḍhā	(δ,ε) Sgr	δ Sgr	(δ,ε,γ,λ) Sgr	λ Sgr	(δ,ε) Sgr	δ Sgr
19 U Aṣāḍhā	(ζ,σ) Sgr	σ Sgr	(ζ,σ,τ,φ) Sgr	τ Sgr	(ζ,σ,τ,θ) Sgr	σ Sgr
20 Abhijit	(α) Aql	α Aql	(?) Vega	α Lyr	(α,ε,ζ) Lyr	α Lyr
21 Śravaṇa	(β) Del	β Del	(α,β,γ) Aql	α Aql	(α,β,γ) Aql	α Aql
22 Dhaniṣṭhā	(β) Aqr	β Aqr	(α,β,γ2,δ) Del	β Del	(α,β,γ,δ) Del	β Del
23 Śatabhiṣak	(α) PsA	α PsA	(λ) Aqr	λ Aqr	(λ) Aqr + 100	λ Aqr
24 P Proṣṭapada	(α,β) Peg	α Peg	(α,β) Peg	α Peg	(α,β) Peg	α Peg
25 U Proṣṭapada	(λ) Peg	λ Peg	(γ) Peg, (α) And	γ Peg	(γ) Peg (α) And	γ Peg
26 Revatī	(ζ) Psc	ζ Psc	(ε,(α,ζ)) Psc	ε Psc	(ζ) Psc + 31	ζ Psc
27 Aśvayuk	(α,β) Ari	β Ari	(α,β,γ) Ari	β Ari	(β,γ) Ari	β Ari
28 Bharaṇī	(35,39,41) Ari	41 Ari	(35,39,41) Ari	41 Ari	(35,39,41) Ari	41 Ari