

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

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ज्योतिः शास्त्रम् (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)

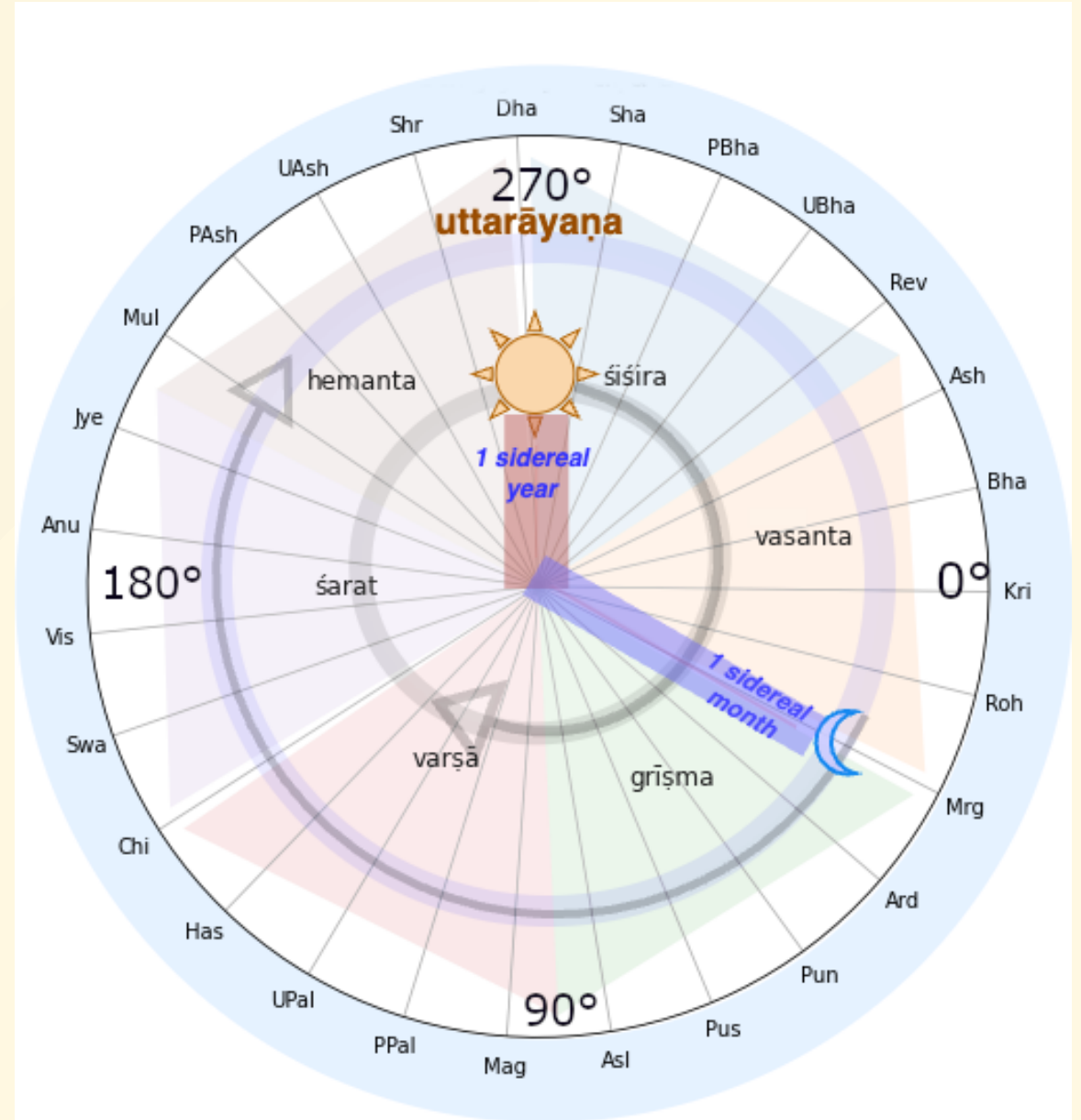
- Big text ~5000 verses and some prose, 24 *aṅga*-s, 40 *upāṅga*-s
- CAHC has published a critical edition of 5 chapters of 1st *aṅga*

Focus of this talk - two **Sun Transit** chapters of VGJ

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

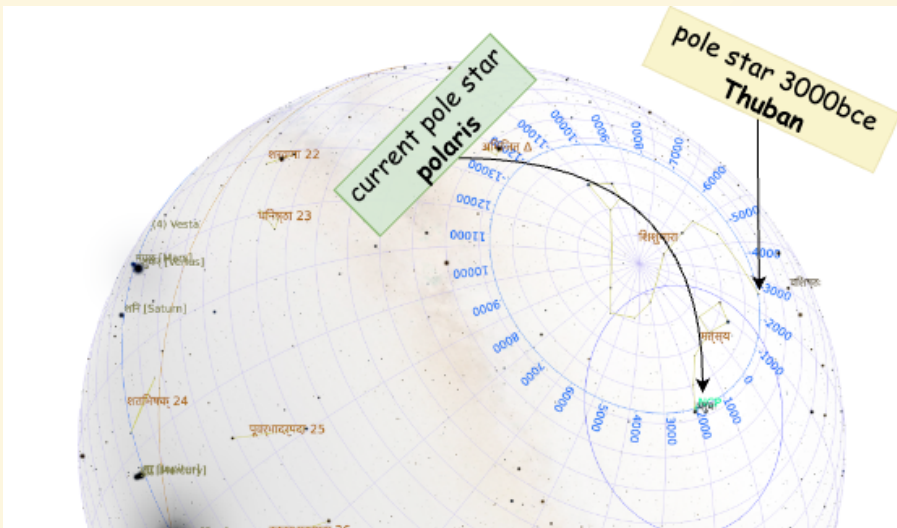
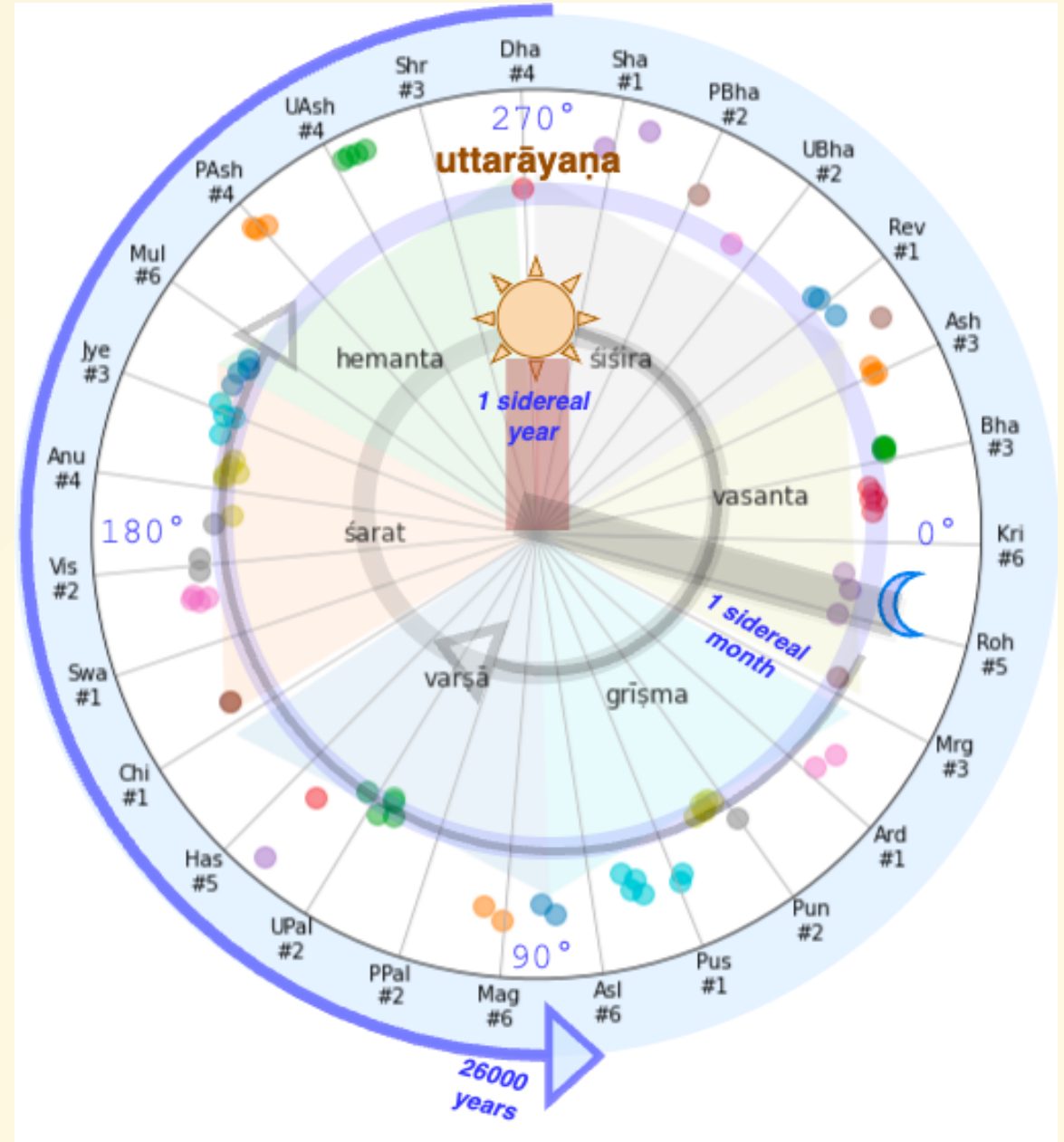
Nakṣatra-s

- Zones in the sky through which Moon, Sun and planets travel
- 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 . In one year, the Sun makes
 - one **dakṣiṇāyana** (north-to-south) and
 - one **uttarāyana** (south-to-north) journey
- Some *nakṣatra-s* are unambiguously identified
 - कृत्तिका, रोहिणी, मघा, हस्ता, चित्रा, स्वाति, विशाखे, ज्येष्ठा, मूला
- Others have some ambiguity
 - आर्द्रा, श्रविष्ठा/धनिष्ठा, रेवती



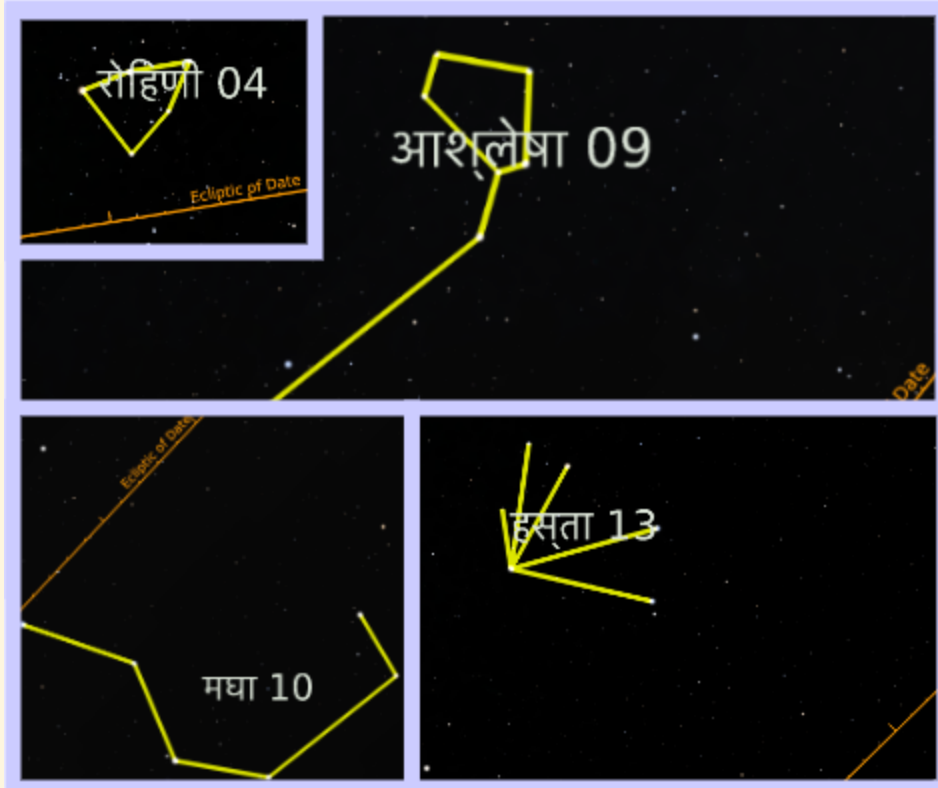
Equinox & Precession

- **Equinox** is the midpoint of
 - The sun's *dakṣiṇāyana* & *uttarāyana* journeys
- **Precession** - The *nakṣatra* dial also rotates
 - In direction opposite to Sun/Moon hand
 - And takes ~26000 years to complete a round
- This precession has the following effects
 - The *nakṣatra* marking the seasons/equinoxes **move by 1 *nakṣatra* every ~1000 years**
 - the pole drifts from *abhayadhruva* (thuban) around -3000 to around *dhruva* (polaris) now



Nakṣatra Listings

- The table shows **83 stars** of the *nakṣatra*-s
- each *nakṣatra* has 1 or more **constituent stars**
- Vedic, Jaina & Baudha texts have **astrograph and count** information
- **Proxy stars** for each *nakṣatra* help model आदी, अर्ध, अन्त in the text

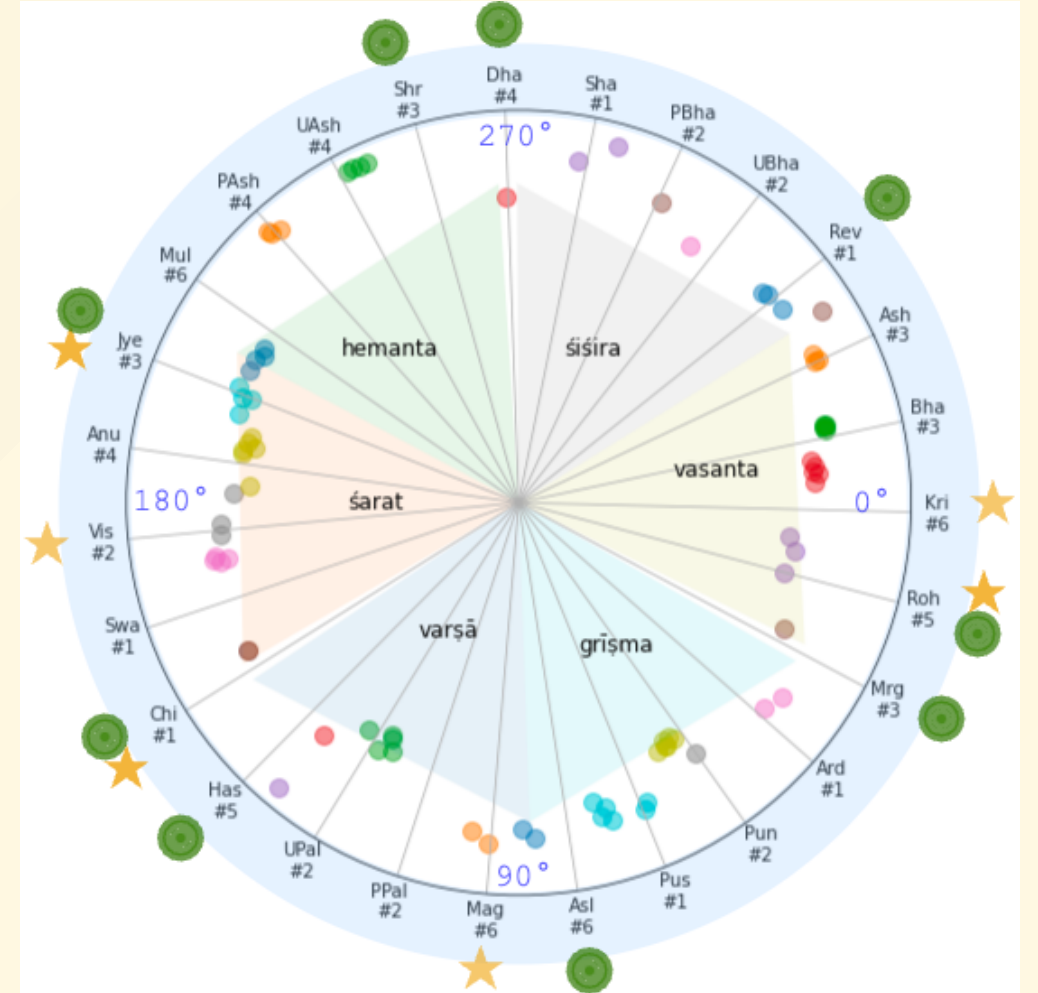


#	Nakṣatra	Star Count					Astrograph	Constituent Stars	Proxy Star (Author's)	Abhyankar's Yogatara
		VGJ	PT	AVP	SKA	SCP*				
1	Kṛttikā	6	6	6	6	6	Knife/Cleaver	(17, 19, 20, 23, 27, η) Tau	η Tau	η Tau
2	Rohiṇī	5	5	1	5	5	Cart	(α, γ, δ1, ε, θ2) Tau	α Tau	α Tau
3	Mṛgaśīra	3	3	3	3	3	Deer's Head	(α, γ, λ) Ori	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	Kilaka (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	Jyēṣṭhā	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 Aśādhā	4	4	4	4	4	Gajavikrama (Elephant Step)*	(γ, δ, ε, λ) Sgr	λ Sgr	δ Sgr
19	U Aśādhā	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	ऋतु
श्रविष्ठादीनि चत्वारि पौष्णार्धज्य दिवाकरः । वर्धयन् सरसस्तिक्तं मासौ तपति शैशिरे ॥ 47	श्रविष्ठा आदी	रेवती अर्ध	शिशिर
रोहिण्यन्तानि विचरन् पौष्णार्धाद्याच्च भानुमान् । मासौ तपति वासन्तौ कषायं वर्धयन् रसम् ॥ 48	रेवती अर्ध	रोहिणी अन्त	वसन्त
सार्पार्धान्तानि विचरन् सौम्याद्यानि तु भानुमान् । ग्रेष्मिकौ तपते मासौ कटुकं वर्धयन् रसम् ॥ 52	मृगशिरा आदी	आश्लेषा अर्ध	ग्रीष्म
सावित्रान्तानि विचरन् सार्पार्धाद्यानि भास्करः । वार्षिकौ तपते मासौ रसमम्लं विवर्धयन् ॥ 53	आश्लेषा अर्ध	हस्ता अन्त	वर्षा
चित्रादीन्यथ चत्वारि ज्येष्ठार्धज्य दिवाकरः । शारदौ लवणाख्यं च तपत्याप्याययन् रसम् ॥ 54	चित्रा आदी	ज्येष्ठा अर्ध	शरद्
ज्येष्ठार्धादीनि चत्वारि वैष्णवान्तानि भास्करः । हेमन्ते तपते मासौ मधुरं वर्धयन् रसम् ॥ 55	ज्येष्ठा अर्ध	श्रवण अन्त	हेमन्त

- Similar information is found in the PT as prose
 - Maps each of 6 ऋतु to a span $4\frac{1}{2}$ *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 नक्षत्राणि 27 proxy stars 83 constituent stars	50 years around 1250 BCE

आदित्यचारः - date estimation

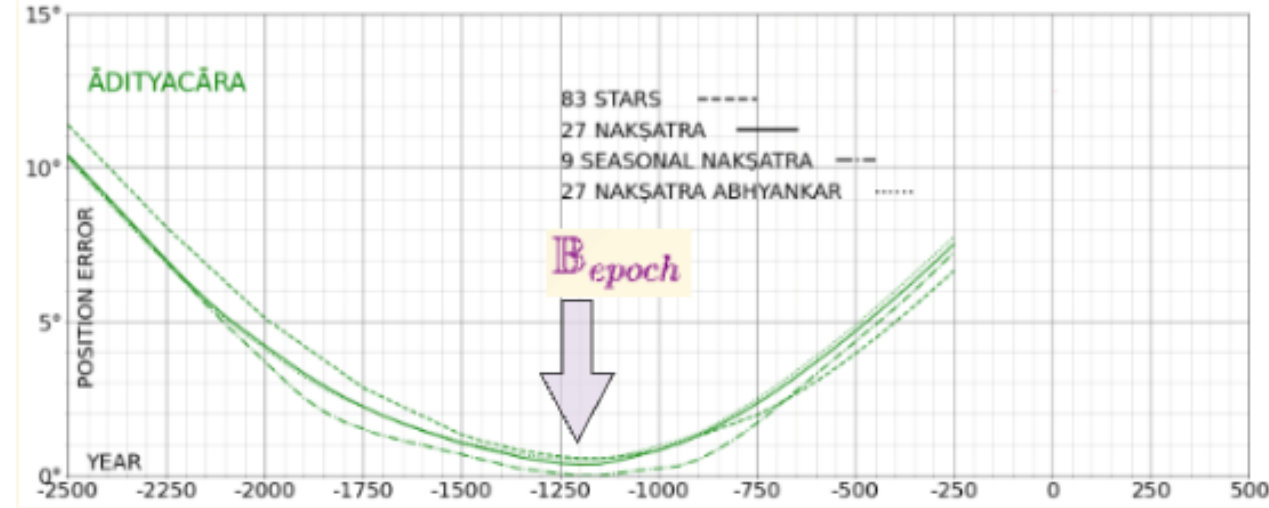
- From the text
 - *nakṣatra*-s are equally spaced at 13.33° - given seasons are of equal of $4\frac{1}{2}$ *nakṣatra*-s
 - शिशिर start is sun with श्रविष्ठादि taken as 270°
 - Given the *nakṣatra*-s sequence and above, span of each *nakṣatra* is obtained
- The **best fit method** finds the epoch where most *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}

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

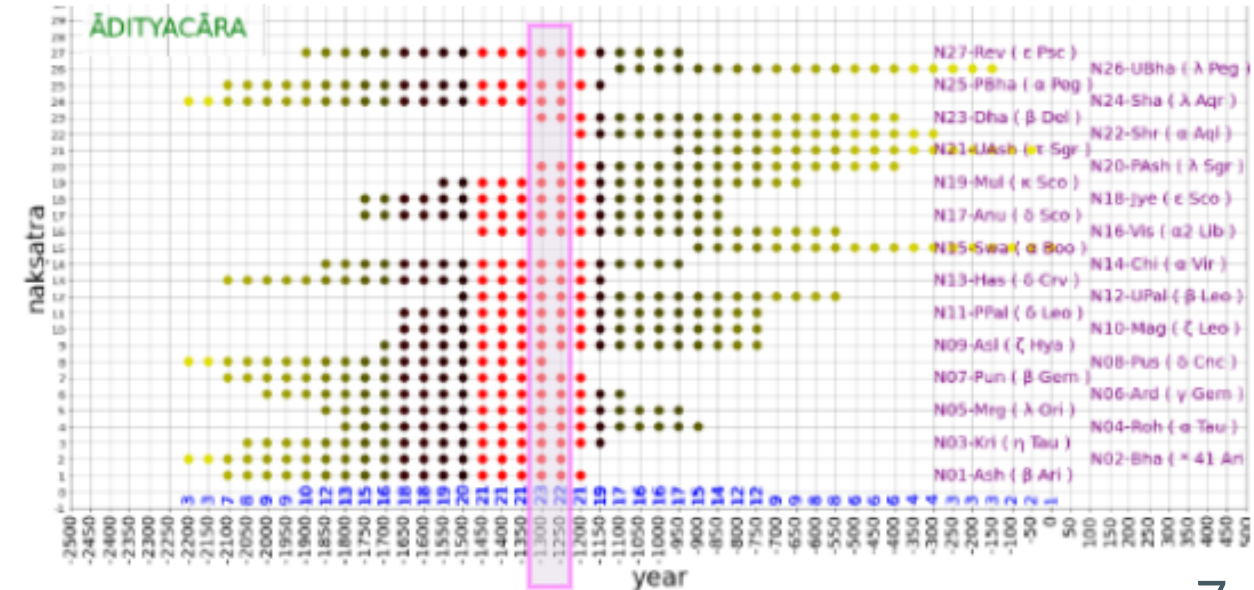
$$\mathbb{E}_{epoch} = \frac{1}{27} \sum_{\tau=1}^{27} \frac{\sum_{t=1}^{T_\tau} err_{\tau,t}}{T_\tau}$$

$$err_{\tau,t} = \begin{cases} 0, & \text{if } long_\tau < long_t < long_{\tau+1} \\ \text{else} & \min(|long_\tau - long_t|, |long_{\tau+1} - long_t|) \end{cases}$$

Error Plot - Minima at ~ -1250 indicates best fit



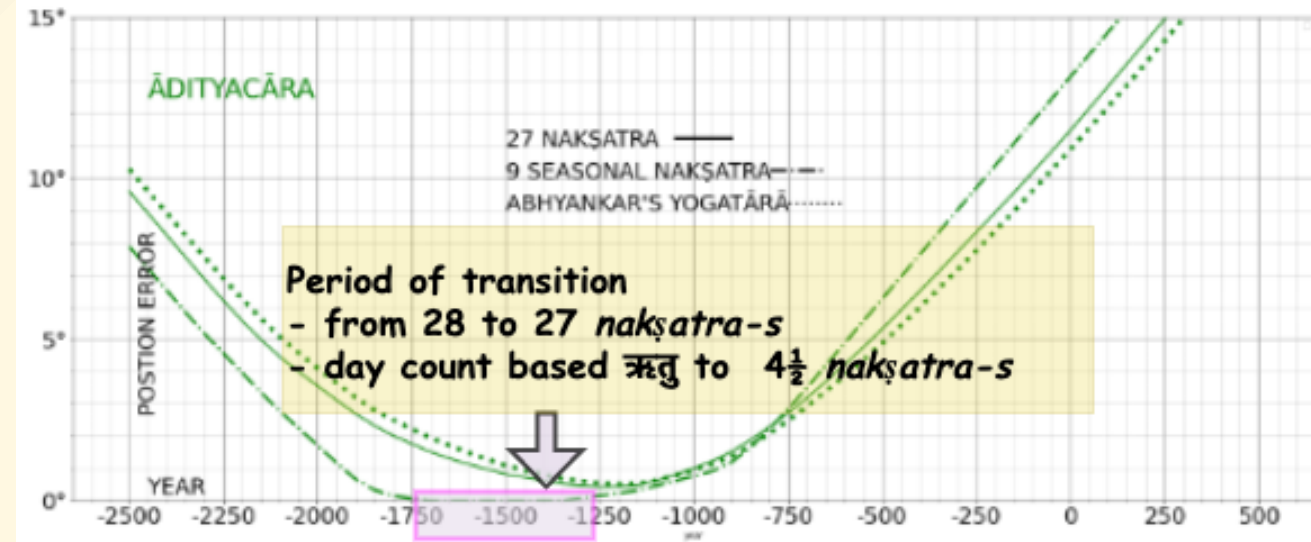
Containment Plot - Maxima at ~ -1250 indicates best fit



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

- Winter solstice drift can be seen
 - श्रविष्ठार्धा in MAU to
 - श्रविष्ठादि in PT/VGJ
 - towards अभिजित in MB
- At some point in the transition period
 - धनिष्ठा is named the winter solstice *nakṣatra*
 - अभिजित is eliminated to pack 6 ऋतु of $4\frac{1}{2}$ *nakṣatra*-s
 - the 27 नक्षत्राणि regime takes hold over the 28
- Validating the transition period with
 - श्रविष्ठा as β Aqr (श्रवण post transition)
 - श्रवण as β Del (धनिष्ठा post transition)
 - the 9 seasonal *nakṣatra*-s remain in bound from 1700-1350bce
- The 6 ऋतु system
 - started around 1700 BCE with day counts and
 - stabilized around 1300 BCE with $4\frac{1}{2}$ *nakṣatra*-s per ऋतु

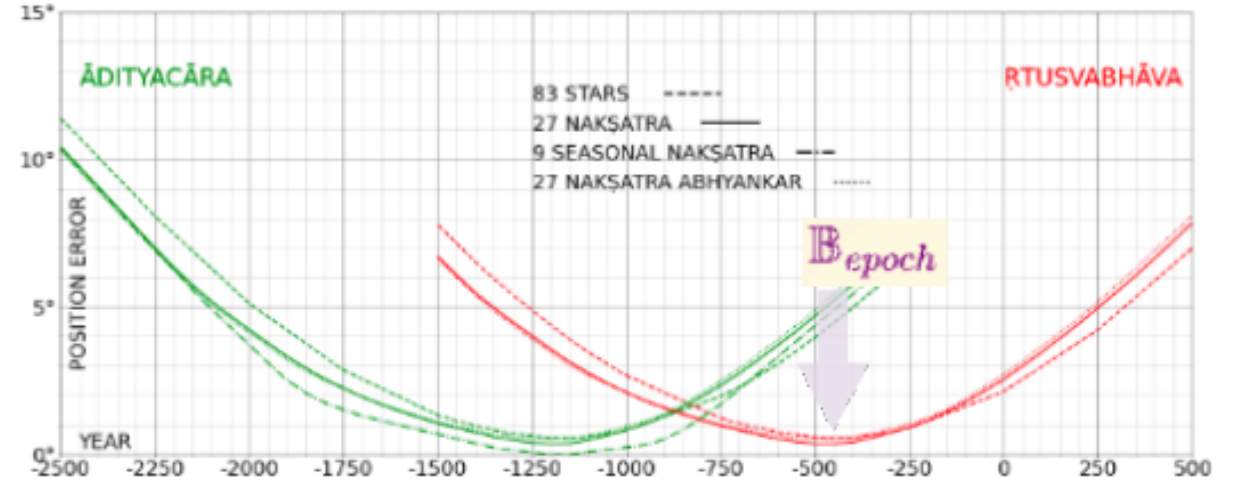
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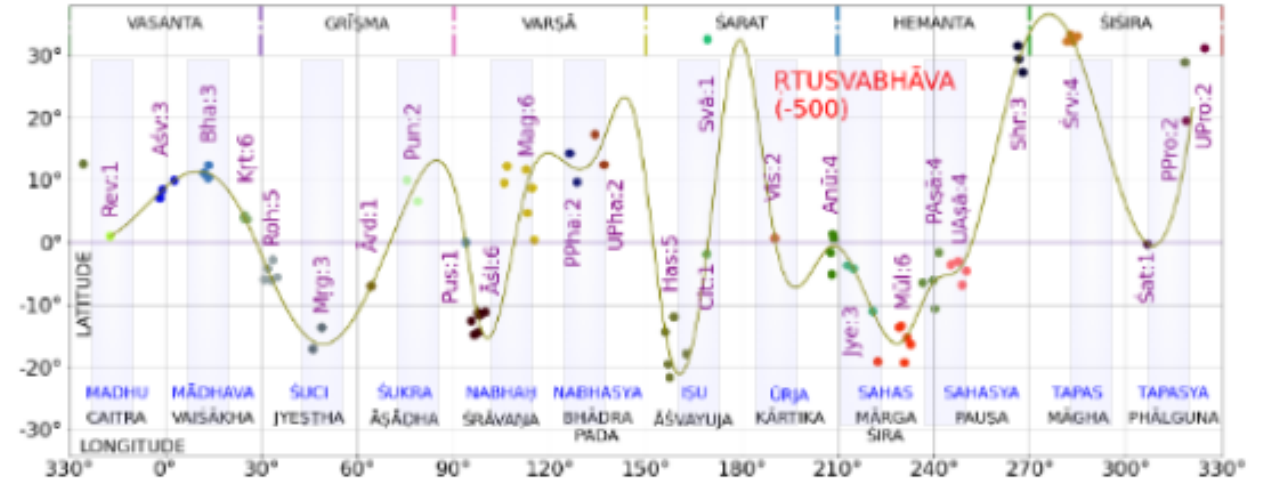
ऋतुस्वभावः

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

Minima at ~ -500 indicates best fit for ऋतुस्वभावः



ऋतुस्वभावः - *nakṣatra*-s, *vaidika* & *laukika* months



In closing

- ऋतु based sun transit started around -1700 with 61 day count
- आदित्यचार: observations date to about -1250 with $4\frac{1}{2}$ *nakṣatra*-s span per season
- ऋतुस्वभाव: observations date to about -500 with 12 solar months
- VGJ is layered and contains information across generations of observations and inferences
- Solar transit (zodiac) is certainly part of original Indian knowledge - that has been recorded and evolved over time