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

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5-Nov-2022, BIHS Mumbai

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 *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

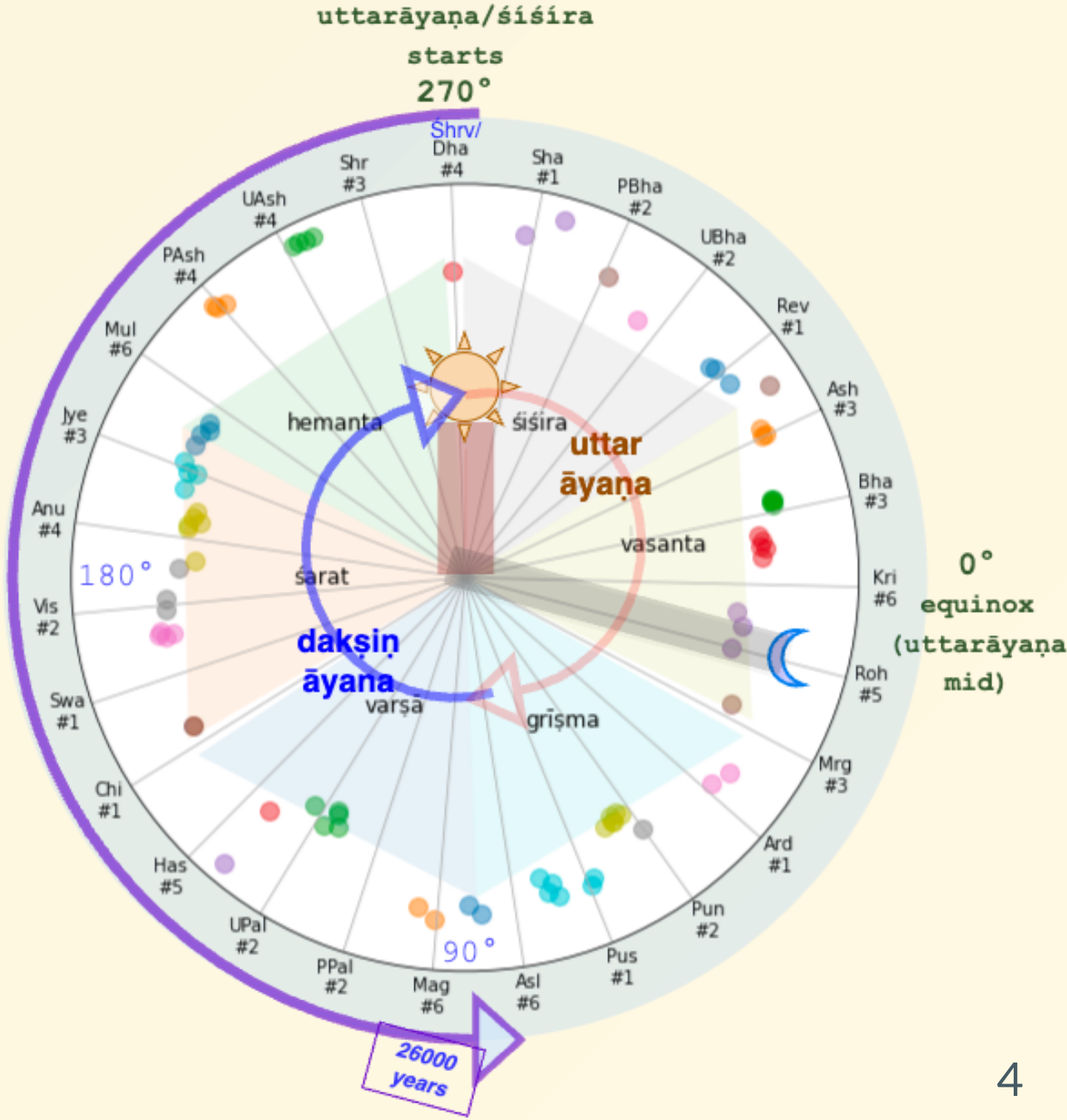
- An observer watching every sun rise through the year will see this swing

	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

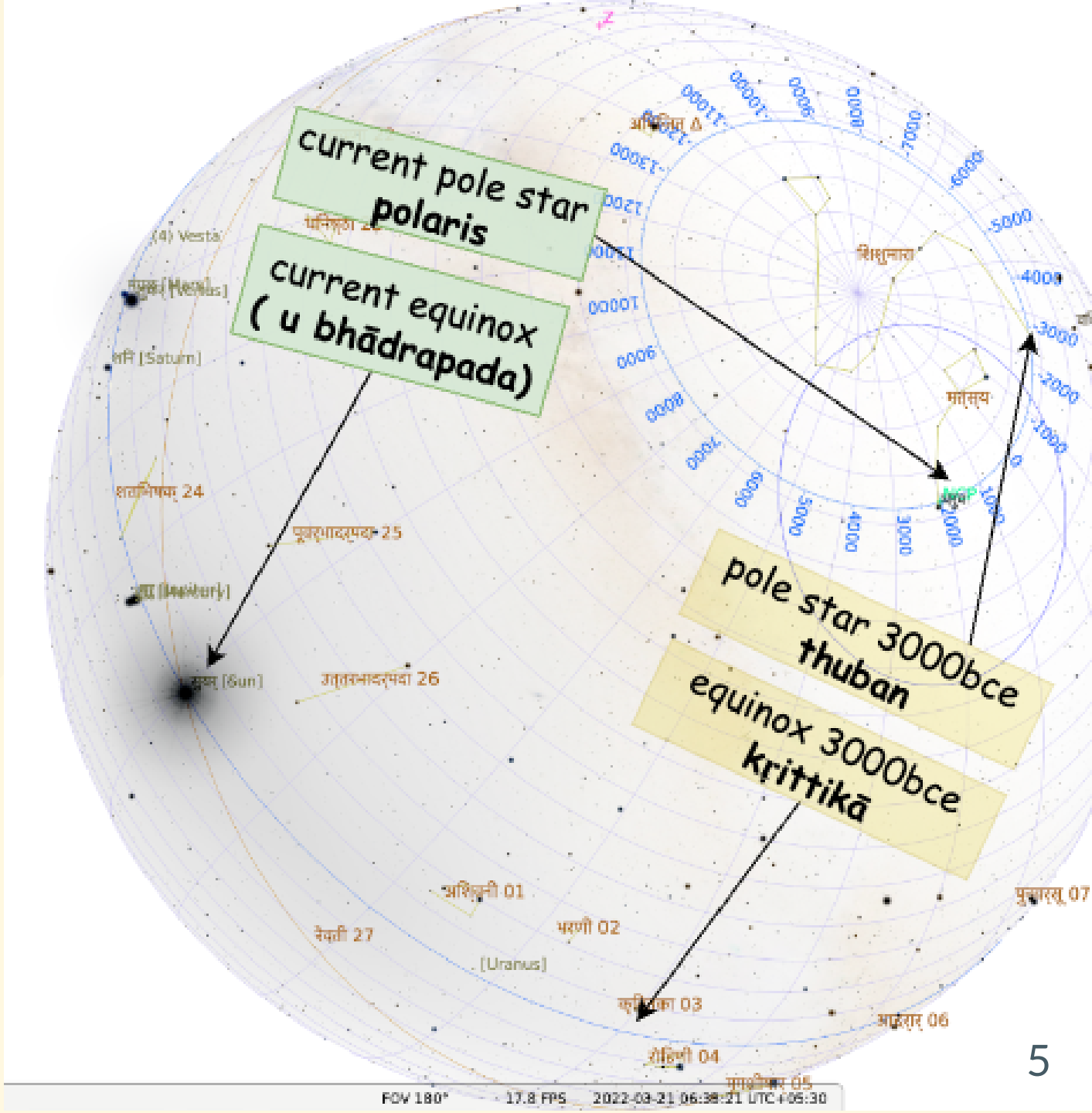
Nakṣatra-s

- **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

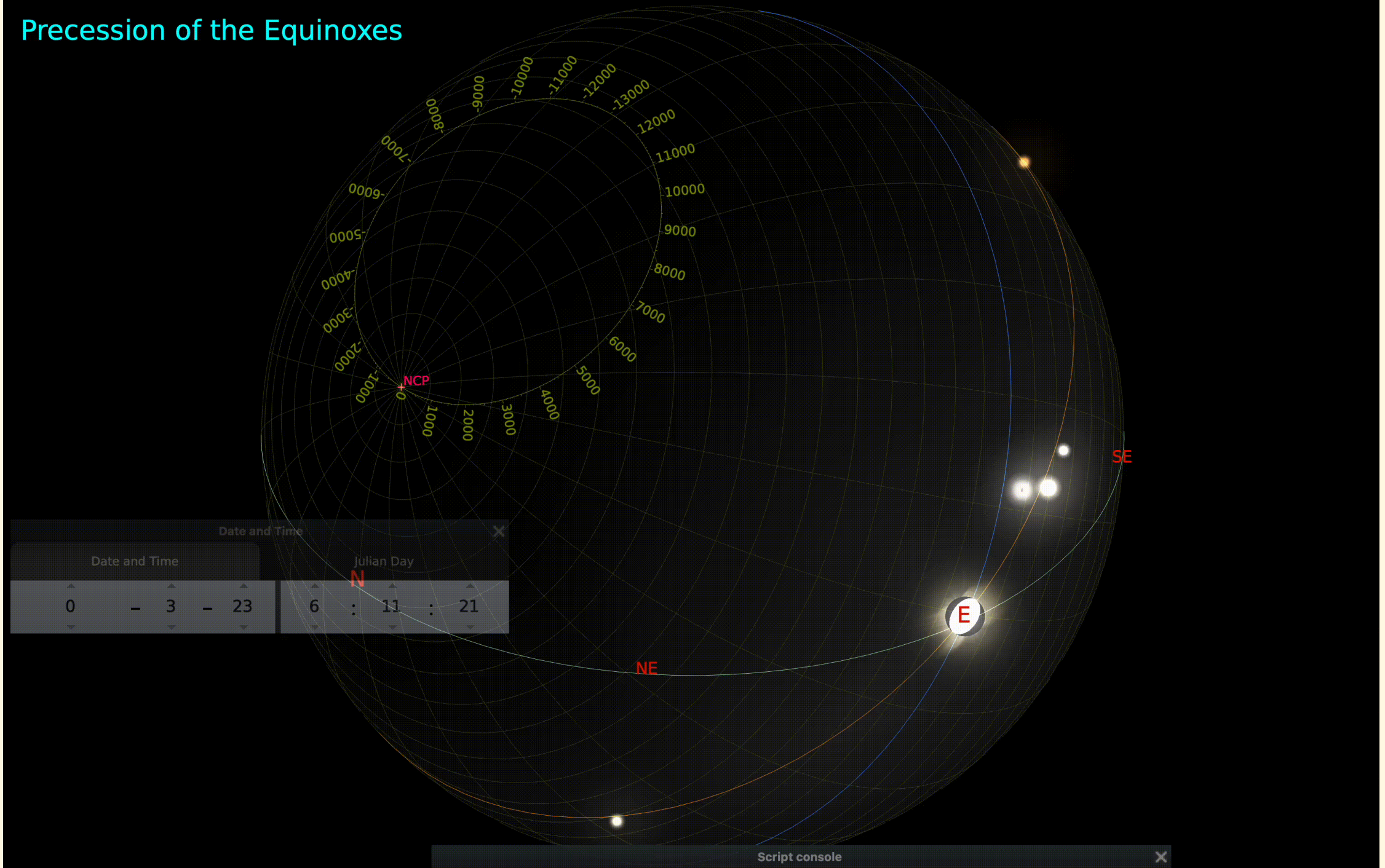


Precession

- **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 *nakṣatra* 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

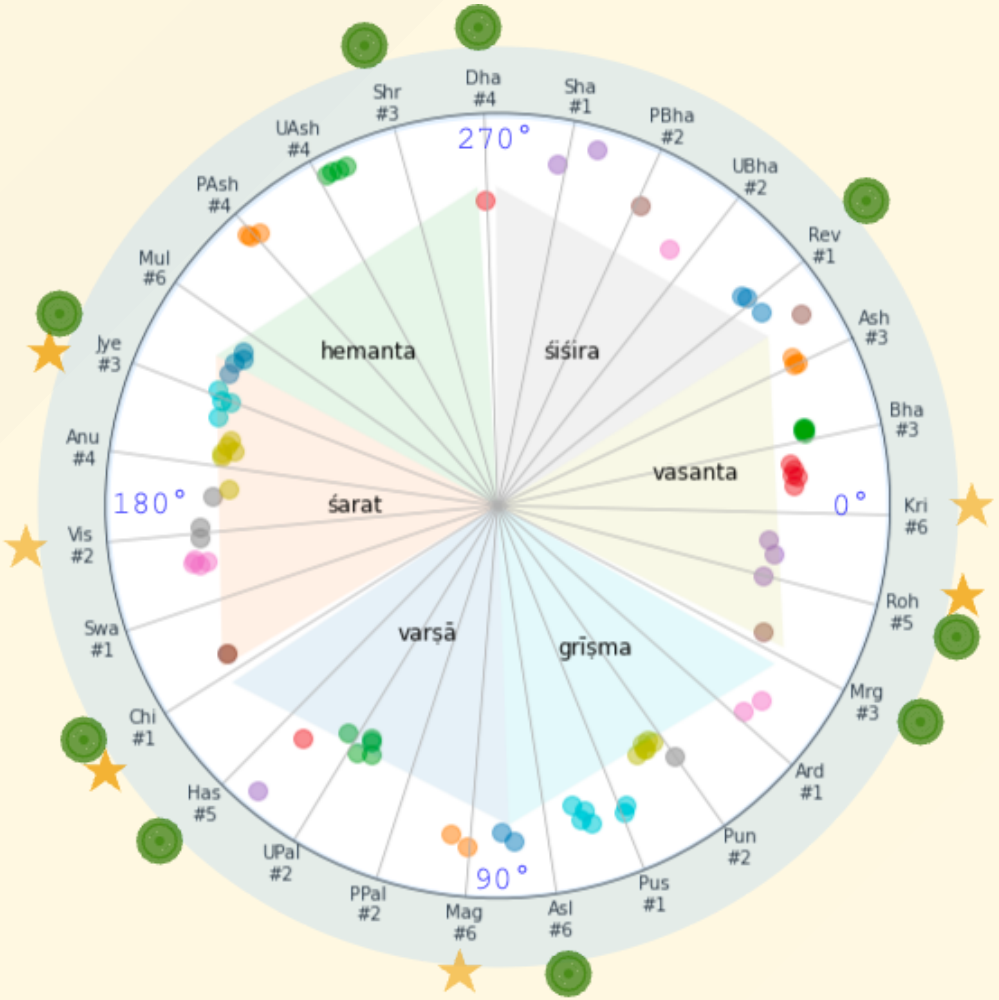
- The table shows **83 constituent stars** of the *nakṣatra-s* per VGJ
- Vedic, Jaina & Baudha texts have **astrograph and count** information
- **Proxy stars** for each *nakṣatra*, help model the **ādi, ardha, anta** (begin, mid, end) in the text
- A few astrographs

#	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*

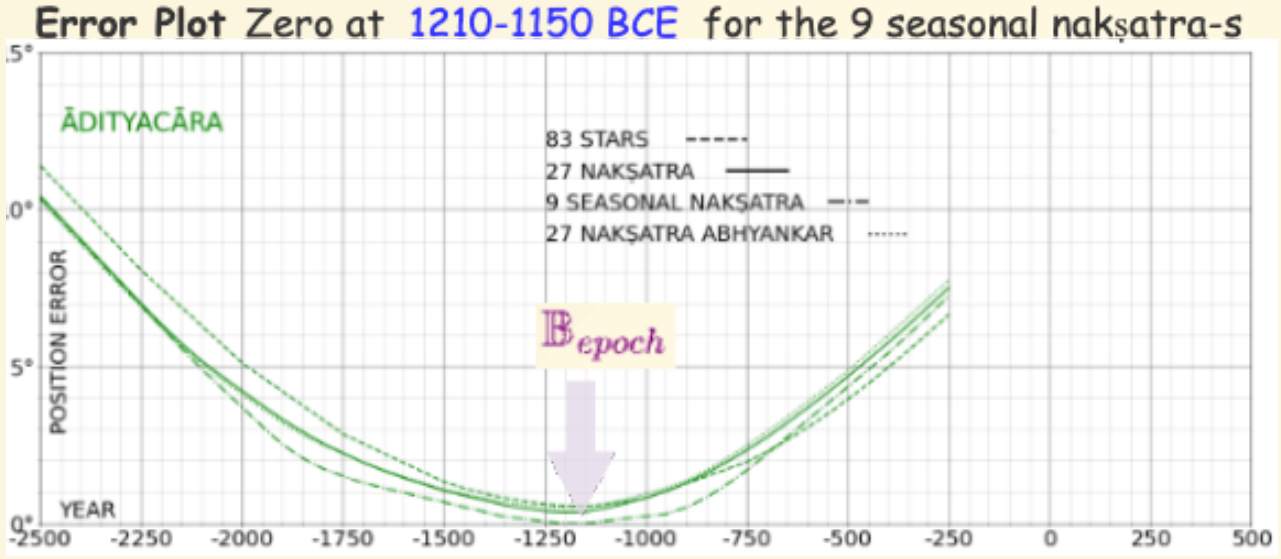
आदित्यचारः - date estimation

- 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 $\mathbb{B}_{epoch}$

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

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

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



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

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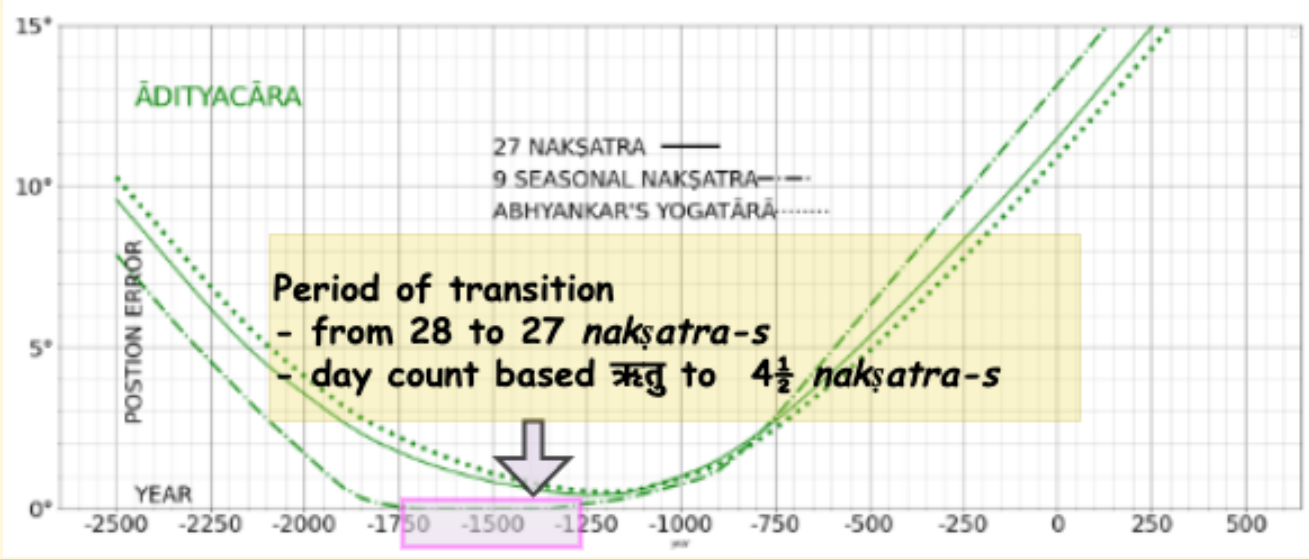
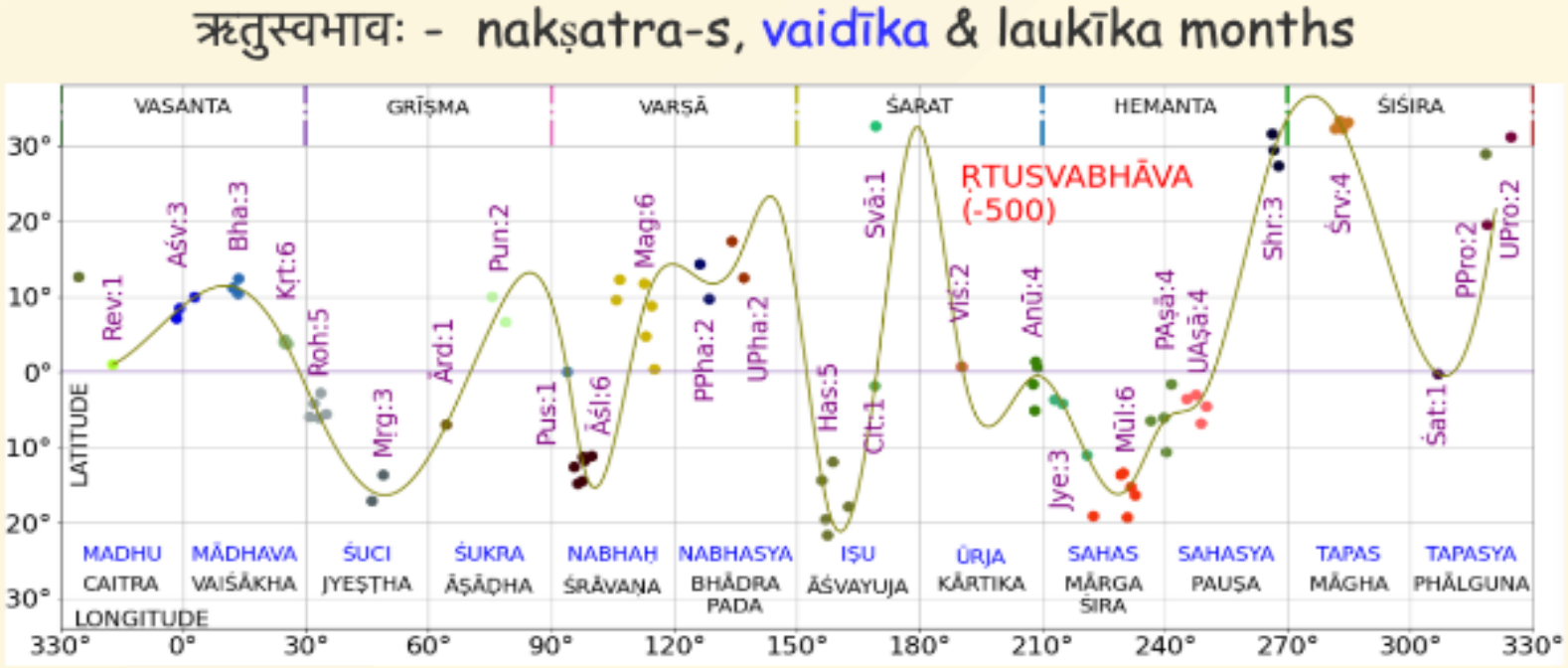
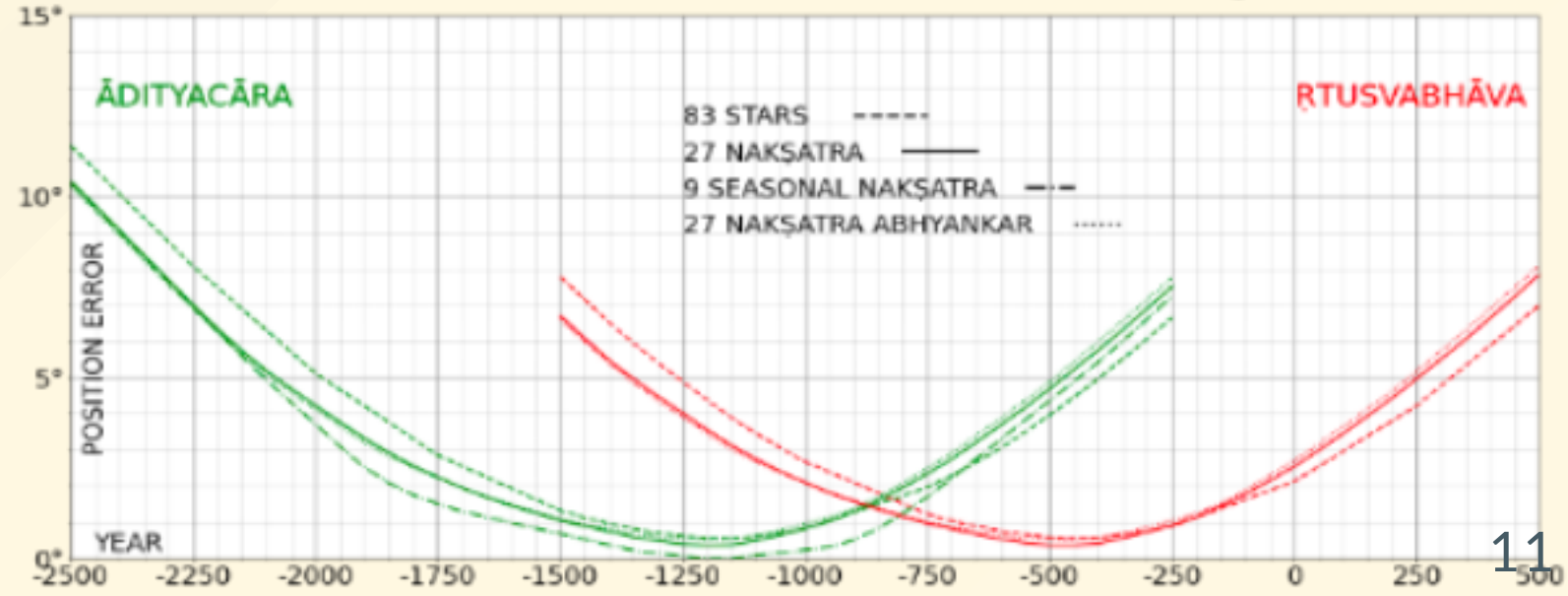


ऋतुस्वभावः

- 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