Foundations and Frontiers of Indian Traditional Astronomical Knowledge and Practice

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Abstract

The unending sky in no-moon night for philosophers is as interesting as that of the full moon night for poets. Night sky observation is as old as our civilization. Astronomy is the earliest scientific exploration both in modern and ancient times. Indian traditional knowledge is noteworthy. Most of the Indian astronomical knowledge is embedded in *Vedic* as well as *Siddhantic* texts. Comets like *Dhumaketu*, astronomical objects like *Soma* or moon are found in *Vedas* and the phenomena eclipse is nicely and explained in *Vedic* texts. The position and relative motions of the constituents of solar system with reference to terrestrial and celestial circles and spheres are described in *Siddhantic* texts. Circumference of planetary orbits, planetary distances and ratio thereof, Circumference of Sïgma epicycle of planets, sidereal periods of planets, inclinations of the orbits of planets to the ecliptic, the greatest equations of Sun and Moon, Ayana Chalan rates were calculated with precision by Indian astronomers and were described in *Siddhantic* texts. The time measuring units like Truti, which is of the order of microseconds and Brahma of the order of several billion years were being used in *Siddhantic* texts. Several instruments for time and distance measurement, models to showcase planetary positions are being used by Indian astronomers from time immemorial. The phenomena and physics of Indian traditional astronomical knowledge is explained in this communication. In Indian astronomy, the differences in the motion of planets have been explained in detail. The compilation of *Panchangam* is a significant aspect of the Indian scientific tradition. Planetary observatories have been incorporated in *Panchangam*. The traditional astronomical understanding of Indians in our religious and cultural practice is decoded in this communication.

Key words: astronomy, terrestrial circles, celestial circles

Introduction:

Sky is the treasure of wisdom and night sky observation is a source of knowledge since time immemorial. When there was no telescope, human being unveiled many a mystery by naked eye astronomy. The values, Indian astronomers, assigns to some of constants of astronomy, are almost same with those used by modern scientists. (Ray, 1899) The error in sidereal period, published by the last astronomer in *Siddhantic* tradition, *Samanta Chandrasekhar*, was 206s for Sun, 1s for Moon, 79 s for Mercury, 2 min for Venus, 9 min for Mars, 1 hour for *Guru* (Jupiter), half a day for Saturn! The accuracy with which the inclination of planets to ecliptic was measured by India astronomers, in naked eye astronomy is still more remarkable. (Ray, 1899) Mercury offers the largest possible errors and this is only 2 minutes!

This confirms the glorious tradition of experimentation in India and India Knowledge System does is not rest solely on theoretical foundation, as is perceived by, rather a strong foundation of experimentation is underneath. *Samanta Chandrasekhar* as he himself writes in *Siddhant Darpan* studied all the earlier *Siddhantic* texts and after independence observation and calculations, estimated many a constant in astronomy. The values published by *Samanta Chandrasekhar* almost same with those published by modern astronomers using advanced telescopes of present time. (Ray, 1899)

In this communication the foundation of Indian astronomy from *vedic* period and the frontiers of modern Indian astronomy of eighteenth century is described in a nut shell. In *Vedic* text comets like *Dhumaketu*, astronomical objects like *Soma* or moon are described. (Iyengar, 2016) It is noteworthy that, the phenomena eclipse is nicely and explained in *Vedic* texts. (Iyengar, 2016) The constellation *Śiśumāra* (Draco) and the Pole Star *Dhruva* finds their place in *Vedic* texts. *Maruts* representing *winds* by *Vedic* scholars. The description of meteoritic storms in vedic texts represents relationship between comets and storms. (Iyengar, 2016) The *Siddhantic* owes to great scholars like, *Aryabhatta* (476 – 550 AD), *Varahamihir* (505-587 AD), *Brahmagupta* (598 – 668 AD), *Bhaskar – I* (600 – 680 AD), *Satananda* (1068-1099 AD), *Bhaskaracharya* (1114-1185 AD), *Kamabhatta, Samanta Chandrasekhar* (1835-1904 AD). The Sanskrit texts like *Aryabhattiya, Arya-Siddhanta, Pancha-sidhantika, Aryabhattiya Bhasya, Bhasvati, Siddhanta Siromani* are noteworthy master pieces written by astronomers of *Siddhantic* tradition in India.

Astronomy in *Vedic* Literature:

In India the social and cultural life of its inhabitants are embedded in *vedic* tradition. Even Indian philosophical pillar is classified with reference to *vedic* belief. The orthodox school of Indian philosophical system was evolved justifying *vedic* knowledge and wisdom, whereas the heterodox school of Indian philosophical system took shape refuting *vedic* beliefs. Astronomical knowledge of *vedic* saints is noteworthy. The *Vedanta, Purana* and related texts are nothing but post-*vedic* literature that decodes the *vedic* knowledge and make the learner understand the *vedic* wisdom.

It is noteworthy that v*edic* literature and culture personifies celestial objects with their actions. When somebody read that a demon (*asura*) fell from the sky and went underground, we can safely infer that this picture should have been probably correlated in time and space with a meteorite fall. (Iyengar, 2016) Similarly when it is said that an *āsura* covered Sun, we may suspect this event to be an eclipse. (Iyengar, 2016) This allegorical approach was known to the *vedic* tradition and system to express the facts. It is believed that *Yāska* records interpretations of the *Ṛgveda*. These interpretations or meaning may be classified as the *adhiyajña, adhyātma* and the *adhidaiva;* the sacrificial, philosophical and celestial (divine) meanings respectively. The *adhidaiva* meaning of the word *Soma* is Moon, whereas in a *vedic* sacrifice as per the *adhiyajña, Soma* is a creeper of that name. (Iyengar, 2016) In the *Upaniṣads* the philosophical meaning of Soma is *manas* or mind. (Iyengar, 2016) The *Śatapatha Brāhmaṇa* (ŚB) has the esoteric statement:

candramā vai somo devānāmannam tā pourṇamāsyāmabhiṣuṇvanti || (ŚB. 11.1.5)

Moon is Soma. Gods get food from her; they approach her on Full Moon.

In Brahmāṇḍa Purāṇa (BP) it is written that (Iyengar, 2016)

āpūrayan suṣumṇena bhāgam bhāgamahaḥ kramāt |
suṣumṇā āpyāyamānasya śuklā vardhanti vai kalāḥ || BP. I. (23.61)

The bright parts (of moon) increase in the *śukla pakṣa*, enlighten by *suṣumṇā* ray of Sun. (Iyengar, 2016)

Bhakṣārtham amṛtam somaḥ pourṇamāsyām upāsate | ekām rātrīm suraiḥ sarvaiḥ pitṛbhiḥ sarṣibhiḥ saha || somasya kṛṣṇapakṣādau bhāskarābhimukhasya tu | prakṣīyante pitṛdevaiḥ pīyamānāḥ kalākramāt || trayaśca trimśataścaiva trayaḥtrimśat tathaiva ca | trayaśca trisahasrāśca devāḥ somam pibanti vai || ityetaiḥ pīyamānasya kṛṣṇā vardhanti vai kalāḥ | kṣayanti tasmāt śuklāśca kṛṣṇā āpyāyayanti ca || BP.I. (23.66-69)

Moon delivers nectar to deities, *Ṛṣis* on Full Moon. Three hundred and three, then thirty-three and again three thousand and three gods drink soma. Being drunk this way, the dark digits increase with corresponding decrease in the bright digits. Over a long period of time the effect of precession was also felt as with the loss of importance for the constellation *Śiśumāra* (Draco) and shifting of the Pole Star *Dhruva.* (Iyengar, 2016)

In Brahmāṇḍa Purāṇa (BP) it is further written that (Iyengar, 2016)
tatomandataram nābhyām cakram bhramati vai tathā| mrtpiṇḍa iva madhyastho dhruvo bhramati vai tathā || trimśanmuhūrtānevāhuḥ ahorātram dhruvo bhraman| ubhayorkāsṣṭhayormadhye bhramte maṇḍalāni tu || kulāla cakranābhiśca yathā tatraiva vartate|
dhruvastathāhi vijñeyastatraiva parivartate|| *BP. I (21. 94, 95, 96)*

Dhruva rotates and moves in circles day and night consisting of 30 *muhūrtas*. (Iyengar, 2016) Like the nave of the potter's wheel stays in the same place, so also Dhruva should be known to be rotating there itself. (Iyengar, 2016)

In the *Ṛgveda* (RV) *sūkta* (V.40) the solar eclipse is described. (Iyengar, 2016) By going through this hymn one can appreciate the epithets and terminologies used. The translation of the verse can be like this

> Oh Sun! When *svarbhānu* the *āsura* struck you with darkness the worlds became like a person not knowing where he stood. (Satpathy, 2003)
>
> *Indra*! While you were removing the illusions of *svarbhānu* that spread
>
> below the sun, *Atri* by his fourth prayer rescued Sun concealed by darkness. (Naik & Satpathy, 1995)
>
> Let not the violator devour me with darkness. You are *Mitra* whose wealth is truth. Let you and King *Varuṇa* protect me. (Mohapatra , 1899)
>
> Then, *Atri* bringing the stones together, offering prayers to deities dispelled the darkness and placed the eye of Sun in the sky. (Samanta, 2012)
>
> Only the *Atris* and none others, could subsequently find Sun whom *asura svarbhānu* struck with darkness. (Naik & Satpathy, 1998)

The above verses address *Indra*. The event is popularly known as *Atri's* eclipse. Here, it is

Indra who is said to have removed *svarbhānu*. Sun prays to *Atri* along with *Mitra* and *Varuṇa* seeking protection. After this, it is said that *Atri* placed Sun in the sky. The eclipse shadow called *svarbhānu* has the epithet *āsura*, which is popularly rendered as *demon*. They had covered up Sun once. In the hymn RV (V.40) we see the evolution of the concept of an obstruction being called *āsura* a derivative of *asura* who had to be removed by Indra. This is clear link between *āsura* and eclipse shadow. The *rāhu* equated with *svarbhānu* being known as an *asura* in later literature. So, *rāhu* the eclipse causer appears in *vedic* literature first in the *Atharvaveda*. The social and cultural life in India is deeply rooted in *vedic* beliefs and these stories are being transferred from generation to generation through oral traditions. The religious and social rituals during eclipse is carrying this knowledge system, may be in a distorted form.

Astronomy in *Siddhantic* Literature:

The *Siddhantic* tradition in India is praiseworthy. (Ray, 1899) *Samanta Chandrasekhar* (*Pathani Samanta*) was the last flag bearer of *Siddhantic* tradition. He has written *Siddhant Darpan* which is a masterpiece in astronomy. ((Sahoo, 2020), (Satpathy, 2003), (Naik & Satpathy, 1995), (Mohapatra, 1899)) He himself agrees in *Siddhant Darpan* that he studied the earlier *Siddhantic* texts written by *Aryabhatta*, *Satananda, Bhaskaracharya, Kamabhatta* and after independence observation and calculations, did write *Siddhant Darpan.* ((Mohapatra, 1899), (Iyengar, 2016), (Sahoo, 2020)) He estimated many a constant in astronomy and one can find those in *Siddhant Darpan*. The values published by *Samanta Chandrasekhar* accurate if you compare them with the findings of modern astronomers. (Ray, 1899)

Here is the comparison of the results in relation to the values of some of the important constants in astronomy published by different scholars.

Table 1. Inclinations of the orbits of planets to the ecliptic (Naik & Satpathy, 1995)

Planet	***Surya Siddhanta*** ° ′ ″	***Siddhanta Siromani*** ° ′ ″	***Siddhanta Darpana*** ° ′ ″	**Modern value** ° ′ ″
Moon	4 30 -	4 30 -	5 09 -	5 08 33
Mars	1 30 -	1 50 -	1 51 -	1 50 59
Mercury	5 55 -	6 55 -	7 2 -	7 00 18
Jupiter	1 0 -	1 16 -	1 18 -	1 18 18
Venus	2 46 -	3 6 -	3 23 -	3 23 41
Saturn	2 0 -	2 40 -	2 29 -	2 29 10

Inclination of orbits of planets to ecliptic is an important astronomical parameter so far as solar system is concern. In table 1, the estimation of inclination of orbits of planets to ecliptic is given and it is worth noting that *Siddhantic* texts bears accurate and precise measurement of this parameter.

Table 2. Sidereal periods of planets (Naik & Satpathy, 1995)

Planet	***Surya Siddhanta*** (Days)	***Siddhanta Siromani*** (Days)	***Siddhanta Darpana*** (Days)	**Modern value** (Days)
Sun	365.25875	365.25843	365.25875	365.25636
Moon	27.32167	27.32114	27.32167	27.3216615
Mars	686.9975	686.9979	686.9857	686.97982
Mercury	87.9585	87.9699	87.9701	87.969256
Jupiter	4332.3206	4332.2408	4332.6278	4332.589
Venus	224.6985	224.9679	224.7023	224.70080
Saturn	10765.773	10765.8152	10759.7605	10759.23
Moon's Nodes	6794.3948	6792.2535	6792.644	6793.470

Sideral periods of planets to ecliptic is estimated by different Indian scholars like *Aryabhatta, Latadeva, Bhaskaracharya, Samanta Chandrasekhar* and to anyone's utter surprize the values are almost same with that of modern values. It is nothing but remarkable as shown in table 2.

Table 3. Comparison of r/R ratio (Naik & Satpathy, 1998)

Planet	***Siddhanta Siromani***	***Siddhanta Darpana***	**Modern value**
Mars	1.5	1.518	1.52
Mercury	0.37	0.3875	0.387
Jupiter	5.3	5.21	5.2
Venus	0.716	0.725	0.723
Saturn	9	9.47	9.5

Comparison of r/R ratio of different planets is given in table 3. Calculation of Indian astronomers is accurate looking at the modern values.

Table 4. The greatest equations of Sun and Moon (Naik & Satpathy, 1998)

Celestial Body	*Surya Siddhanta* ° ′ ″	*Siddhanta Darpana* ° ′ ″	European value as in 1899 ° ′ ″
Sun	2 10 31	1 55 33	1 55 19
Moon	5 2 46	5 1 10	6 3 41

The greatest equation of Sun and Moon was calculated *by Aryabhatta, Latadeva and Samanta Chandrasekhar* and the results are shown in table 4. The error is negligible if we compare them with European measurement in eighteen century.

Table 5. Circumferences of the orbits in Yojanas (Naik & Satpathy, 1998)

Planet etc.	*Surya Siddhanta*	*Siddhanta Siromani*	*Siddhanta Darpana*
Moon (= p)	324000	324000	306000
Sun (= q)	4331500	4331497.5	47800800
Asterism	259890012	259889850	17208288000
Universae	18712080814×10^6	187120892×10^8	94297796×10^4
q/p	13.96	13.36	156.21

The circumference of orbits of Sun and Moon was calculated by Indian astronomers and the results are shown in table 5. The measurements are just remarkable.

Table 6. Rate of mean motion of planets per day (sexagesimal system) (Naik & Satpathy, 1998)

Planets	Modern value (Lahiri) ° ′ ″	*Brahmagupta Sripati Bhaskar* ° ′ ″	*Samanta Chandra Sekhar* ° ′ ″
Sun	0 59 08.2	0 59/8/10/21 59 8.1725	59/8/10/24/12/30/4/0/4 59 8.1733912
Moon	13 10 35.0	13/10/34/53/0 13 10 34.8833	13/10/34/52/03/49/ 08/02/16/10/11 13 10 34.8677274
Mars	0 31 26.5	0/31/26/28/7 31 26 . 4686	0/31/26/30/06/47/ 44/32/49/03/04 31 26.5018876
Mercury	4 05 32.4	4/05/32/18/28 4 5 32 . 3077	*
Jupiter	0 04 59.1	0/0459/9/9 04 59 . 1525	0/04/59/05/37/0/ 36/41/17/01/51 0 4 59.0936139

Venus	1 36 07.7	1/36/7/44/35 1 36 7.74305	*
Saturn	0 02 01.9	0/02/0/22/51 2 0.380833	0/02/0/26/55/02/ 53/21/02/04/54 0 2 0.4486244
Moon’s	-0 03 10.6	0/03/10/48/20 03 10.8055	0/03/10/47/40 40/27/11/25/13/30 0 03 10.7946317

The rate of mean motion of planets per day is an important astronomical parameter both in mathematical and predictive astronomy. The estimated values of rate of mean motion of planets are shown in table 6. *Brahmagupta* and *Samanta Chandrasekhar*, estimated it with excellent accuracy if we compare these values with that estimated by modern scholar Lahiri.

Table 7. Ayana Chalan rates (Naik & Satpathy, 1998)

SI. No.	**Astronomical work**	**Annual rate**
1	Surya Siddhanta	54"
2	Soma Siddhanta	54"
3	Sakalya Siddhanta	54"
4	Laghu Vashistha	54"
5	Parasara Siddhanta	52.35"
6	Aryastha Stika	46.25"
7	Munjala (quoted by Bhaskar)	59.9"
8	Bhasvati	60"
9	Grahalaghava	60"
10	Siddhanta Darpana	57.615"

The *ayan* chalan rates written in Indian astronomical texts from *Aryabhatta’s* time to *Samanta Chandrasekhar’s* time are given in a tabular form in table 7. The estimated values are nearly same.

Table 8. Circumference of planetary orbits in Yojanas ((Naik, 2005), (Aryabhata, 2013), (Bhaskaracharya, 2011))

Planet	***Aryabhatiyam***	***Surya Siddhanta***	***Siddhanta Siromani***	***Siddhanta Darpana***
Sun	2887668	4331500	4331497	47800800
Mercury	695472	1043209	1043235	18456420
Venus	1776420	2664637	2664623	34655580
Mars	5431296	8146909	8147108	72303600
Jupiter	34250136	51375784	51376035	245832000
Saturn	85114488	127668255	127671803	441237600

The circumference of planetary orbits is estimated by Indian astronomers like *Aryabhatta, Latadeva, Bhaskaracharya, Samanta Chandrasekhar* and the values are comparable with that of modern values. It is shown in table 2.

Table 9. Planetary distances in astronomical unit (Naik, 2005)

Planet	Distance according to Bode's law	Actual distance
Mercury	0.4	0.387
Venus	0.7	0.732
Mars	1.0	1.0
Asteroid belt	2.8	2.68
Jupiter	5.2	5.203
Saturn	10.0	9.539
Uranus	19.6	19.19
Neptune	38.8	30.1
Pluto	77.2	39.5

The planetary distances are shown in table 9 and are compared with actual distance.

Table 10. Ratio of planetary distances (Naik, 2005)

Planet	*Aryabhatiyam*	*Surya Siddhanta*	*Siddhanta Siromani*	*Siddhanta Darpana*	Period in years
Sun	1.00	1.00	1.00	1.00	1.00
Mercury	0.24	0.24	0.24	0.3861	0.24
Venus	0.615	0.615	0.6143	0.725	0.615
Mars	1.88	1.88	1.88	1.5126	1.880
Jupiter	11.86	11.86	11.86	5.1028	11.862
Saturn	29.47	29.47	29.47	9.230	29.450

Ratio of planetary distances of different planets estimated by different Indian scholars is given in table 10. Calculation of Indian astronomers is accurate looking at the modern values.

Table 11. Radii orbit of planets (Naik, 2005)

Planet	*Surya Siddhanta*		Ptolemy	Values of Western astronomers as in 1840s	*Siddhanta Darpana*	
	Even quadrant	Odd quadrant			Even quadrant	Odd quadrant
Sun	1.00	1.00	1.00	1.00	1.00	1.00
Mercury	0.3694	0.3667	0.3750	0.3817	0.386	0.388
Venus	0.7278	0.7222	0.7194	0.7233	0.725	0.727
Mars	1.5319	1.5513	1.5190	1.5237	1.5126	1.5184
Jupiter	5.1429	5.0000	5.2174	5.2028	5.1428	5.2173
Saturn	9.2308	9.000	9.2308	9.5389	9.230	9.4773

Radii of orbits of planets estimated by different Indian astronomer are given in table 11. Calculation of Indian astronomers is more accurate than that estimated by great western scholar Ptolemy in most of the cases, if we compare them with modern values

Table 12. Circumference of Sïgma epicycle of planets in degrees (Naik, 2005)

Planet	***Surya Siddhanta***		***Siddhanta Darpana***	
	Even quadrant	Odd quadrant	Even quadrant	Odd quadrant
Sun	360	360	360	360
Mercury	133	132	139	140
Venus	262	260	261	262
Mars	235	232	238	237
Jupiter	70	72	70	69
Saturn	39	40	39	38

Circumference of sigma epicycle of planets is estimated by different Indian astronomer and is given in table 12. The results are more than excellent since these are estimated with naked eye astronomy.

Table 13. Orbital distance of planets (Sahoo & Mishra, 2025)

Name of Planets	**Perimeters of planets (*Siddhanta Darpan*) (fingers)**	**Perimeters of planets (Modern Value) (10^{11} m)**
Mercury	18	3.59983
Venus	35	6.79833
Mars	72	14.288099
Jupiter	264	48.885343
Saturn	441	90.028928

Orbital distances of planets are very much important in solar and stellar astronomy. The perimeters of planets and their relative values are very useful to design a model solar system. The normalised values of modern astronomers and that of Indian scholar, *Samanta Chandrasekhar* is shown in table 13. The results are more than excellent and most importantly *Samanta Chandrasekhar* estimated them with precision and accuracy using the crude naked eye astronomy.

The theoretical foundation of astronomers in *Siddhantic* tradition was solid and the experimental expertise is tremendous. The comparison of the results of *Siddhantic* tradition with that of modern values shows the glorious scientific tradition in Indian subcontinent.

Conclusion:

The oral and written Indian tradition of transmission of knowledge from generation to generation is noteworthy. Indian tradition of astronomical studies is as old as *vedas.* A detail mathematical and theoretical foundation of astronomy did exist from the time of *Aryabhatta*, more than fifteen hundred years ago. The mathematical astronomy in *Siddhantic* texts is precise and accurate so far as the major astronomical objects in solar system is concern. Inclination of orbits of planets to ecliptic, sideral periods of planets, r/R ratio of five planets in Indian astrology, the greatest equation of sun and moon, circumference of planetary orbits, rate of mean motion of planets, planetary distances, radii of orbits of planets, circumference of sigma epicycle of planets are measured independently by *Aryabhatta, Latadeva, Bhaskaracharya, Samanta Chandrasekhar* and these can be found in the main text of *Aryabhattiya, Surya-Siddhanta, Siddhanta Siromani, Siddhanta Darpan.* Different scholars have compared these results with modern measurement of nineteenth century and the results are at par with modern measurements. The complicated astronomical events like eclipse are explained excellently by our forefathers. The exact time and place of eclipse and its very nature are predicted precisely by the Indian astronomers and it is evident from the prediction placed in Indian Almanacs. In spite of all this when some scholar says or writes anything on the seminal work of an Indian scholar or/and *Ṛṣis* a common question is aired in void by an impatient critic, “What has he or she done after all?” The answer to such a question is written in the pages of the prestigious journal Nature in reference to such a classic *Siddhantic* texts and I quote, “He has devoted his whole life to the one pursuit of knowledge; who has shown the way to original research amidst difficulties serious enough to dishearten men in better circumstances; who has employed his time usefully, instead of frittering it away like the usual run of men of his rank, on a work which guides the daily routine of millions of his countrymen.” (Ray, 1899)

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