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Introduction to Tripraśna Concepts in Indian *Siddhāntic* Tradition of Astronomy

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ABSTRACT

The two branches of science – Mathematics and Astronomy have been given supreme importance in India since Vedic times. *Jyotiṣa*, is one of the six auxiliaries of Vedic knowledge. *Jyotiṣa*, is a practical science which was blended with the life of humans and it plays a vital role right from his day-to-day activities. Computation of the positions of planets is a well-known aspect of the Indian *siddhāntic* tradition beginning with *Āryabhaṭīya* (C. 499 CE). In all Indian astronomical texts, the subject of finding the directions, place and time occupies an important place. These three important issues (*Tripraśna*), viz., direction, place and time (*dik, deśa, kāla*), are discussed in the chapter *Tripraśnādhyāya* in the *siddhāntas*. The important features of the Ecliptic, the celestial equator, the node, the shape of the Earth, the cause of day and night, the rising of the zodiac signs, etc., are discussed in this chapter. As celestial objects are seen as moving on the surface of a sphere surrounding the observer, the *tripraśna* problems involve the use of spherical trigonometry. This paper will briefly account for a few concepts dealt with in the *Tripraśnādhyāya*.

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1.0 INTRODUCTION

यथा शिखा मयूराणां नागाणां मणयो यथा।
तथा वेदाङ्गःशास्त्राणां ज्योतिषं मूर्धनिस्थितम्॥

"Like the crest of a peacock and the gem of the cobra, Jyotiṣa is situated at the top, at the supreme position among the Vedāṅgas", says Lagadha in *Vedāṅga Jyotiṣa.*

India's contribution to the field of astronomy is well known. Astronomy has played a vital role in all aspects of the life of a normal human. The origin of astronomy can be traced back to the Vedas.

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The auxillary part / limbs of the *Vedas* are called *Vedāṅgas.*There are six *Vedāṅgas - Chandhas* (Prosody), *kalpa (*Rituals*), nirukta (*Etymology*), shikśā (*phonetics*), Jyotiśam, vyākaranam (*Grammar*).* The branch of science, *Jyotiśam* comprises these three important sciences: Mathematics, Astrology and Astronomy.

2.0 IMPORTANCE OF PROOFS IN INDIAN MATHEMATICS

In the view of Indian Mathematicians any calculational procedure learnt without upapatti is futile. It is said by Bhāskarācārya in *Golādhyāya* as:

मध्याद्यं द्युसदां यदत्र गणितं तस्योपपत्तिं विना
प्रौढिं प्रौढसभासु नैति गणको निःसंशयो न स्वयम्।
गोले सा विमला करामलकवत् प्रत्यक्षतो दृश्यते
तस्मादस्म्युपपत्तिबोधविधये गोलप्रबन्धोद्यतः॥

Without the knowledge of *upapatti-s* by merely mastering the *gaṇita* (calculational procedures) described here, from the *madhyamādhikara*, of the heavenly bodies, a mathematician will not have any value in the scholarly assemblies; without the *upapatti-s* he himself will not be free of doubt. Since *upapatti* is clearly perceivable in the sphere like a berry in hand, I therefore begin the *golādhyāya* to explain the *upapatti-s*.

Computation of the positions of planets is a well-known aspect of the Indian *siddhāntic* tradition beginning with *Āryabhaṭīya* (C. 499 CE). In all Indian astronomical texts, the subject of finding the directions, place and time occupies an important place. These three important issues (*Tripraśna*), viz., direction, place and time (*dik, deśa, kāla*) are discussed in the chapter *Tripraśnādhyāya* in the *siddhānta*s.

त्रयाणां प्रश्नानां दिग्देशकालानामुत्तरं यत्राभिधीयते स त्रिप्रश्नाधिकारः[1]

As celestial objects are seen as moving on the surface of a sphere surrounding the observer, the *Tripraśna* problems involve the use of spherical trigonometry.

Few important concepts of T*ripraśna* are as follows:

1) Determination of the East–West directions,
2) *Golabandha* – construction of the armillary sphere,
3) *Cara* – The ascensional difference,
4) The rising times of *rāśi s* (zodiacal signs),
5) *Śaṅku* – Gnomon.

3.0 *GOLABANDHA* - CONSTRUCTION OF THE ARMILLARY SPHERE

Golabandha, is a chapter on the construction of the armillary sphere for illustrating various astronomical concepts. In *Siddhāntaśiromaṇi***,** Bhāskara explains how to create the models of the celestial sphere with orbits of the celestial objects. Bhāskara starts with choosing the perfect wood for spheres with the markings of degrees in circles. He emphasises the need for its construction by a mathematician who is also a skilful artisan.

सुसरलवंशशलाकावलयैः श्लक्ष्णैः सचक्रभागाङ्कैः।
रच्चयेद्गोलं गोले शिल्पे चानल्पनैपुणो गणकः॥१॥[2]

[1] Siddhāntaśiromaṇi, Gola, Golabhandhādhikāra
[2] Siddhāntaśiromaṇi, Gola, Golabhandhādhikāra, Verse 1

Bhāskara describes the *bhagola* (Sphere of Asterims), *khagola* (and *dṛggola* (observational sphere) and their relations, and also the various circles as in other texts. He describes the drawing of the diurnal circle for an arbitrary declination. The radius of the diurnal circle is the *dyujyā*, which is the R cosine of the declination of a celestial body. (R cos δ, where δ is the declination):

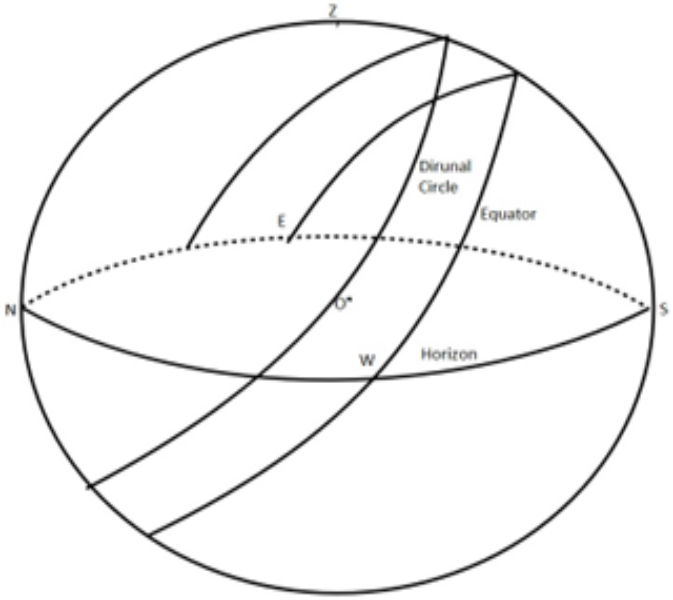
ईप्सितक्रान्तितुल्येऽन्तरे सर्वतो नाडिकाख्यादहोरात्रवृत्ताह्वयम्।

तत्र बद्ध्वा घटीनां च षष्ट्याङ्कयेदस्य विष्कम्भखण्डं द्युजीवा मता॥२७॥[3]

नाडीवृत्तादुत्तरतो दक्षिणतो वा सर्वत इष्टक्रान्तितुल्येऽन्तर यद्वृत्तं निबध्यते तदहोरात्रवृत्तम्। तेन वृत्तेन तस्मिन् दिने रविर्भ्रमतीत्यर्थः। तस्य वृत्तस्य व्यासार्धं द्युज्या॥२७॥

To the north , south, on all sides of the Nādi-valaya, to the measurement of declination, draw a circle , that is the dirunal circle. On that day , in that circle , the Sun revolves.

Figure 1 – *Diurnal Circle*



He also discusses the diurnal circles of the endpoints of the *rāśis*. Bhāskara explains the placing of the *vikṣepamaṇḍalās* (the inclined orbits of the planets, corresponding to the orbits of the moon and planets with latitude) on the *bhagola*. Understanding this chapter plays a vital role in learning Indian Astronomical concepts.

4.0 DETERMINATION OF THE EAST-WEST DIRECTIONS

Fixing the directions is an important and fundamental aspect of traditional astronomy. It is one of the "three questions" in the *Tripraśnādhikāra* chapter of the Indian texts. However, even before the *siddhāntic* period, we have the "Circle method" to fix the east-west line in *Kātyāyana Śulvasūtra* (before 300 BCE):

समे शङ्कु निखाय शङ्कुसम्मितया रज्ज्वा मण्डलं परिलिख्य यत्र

लेखयोः शङ्कग्रच्छाया निपतति तत्र शङ्कू निहन्ति सा प्राची

Here, a gnomon ('*Śaṅku*') is placed at the centre of a circle on level ground, and the points where the tips of the shadows of the gnomon touch the circle, before and after the noon are marked. The line joining the two points is the east-west line.

[3] Siddhāntaśiromaṇi, Gola, Golabhandhādhikāra, Verse 27

5.0 *CARA*

Due to the variation of the declination of the Sun through the year, the duration of daytime (time interval between sunrise and sunset) also varies, for any location other than the equator. This is discussed in all the texts beginning with *Āryabhaṭīya.* The variation of the sunrise time and the durations of the day and night are discussed in detail in all the texts following *Āryabhaṭīya*. The Brahmagupta's *Brāhmasphuṭasiddhānta* discusses the geometrical significance of *cara* and its consequence for the duration of the daytime. In *Śiṣyadhīvṛiddhidha*, Lalla says that when the Sun is in the northern Hemisphere, the horizon is below the *unmaṇḍala* or the 6'oclock circle. Thus, at a place in the north of the equator, Sun rises earlier and sets later than at the equator. The 6'O Clock circle is said to be the reason for the increase or decrease of days and nights. There is no *cara* or ascensional difference at Lanka which is on the equator, and whose latitude is zero. Hence the days and nights are equal at the Equator.

6.0 RISING TIME OF *RĀŚIS*

The rising time of 12 *rāśisMeśa* (Aries), *Vṛṣabha* (Taurus), ……., *Mīna* (Pisces), at any location with latitude is discussed in detail in the Indian Astronomical texts. The procedure is set out extremely briefly in *Āryabhaṭīya*, and explained at length in the commentary of Bhāskara-I. In *Śiṣyadhīvṛiddhidha*, Lalla explains how the rising times of the different *rāśi* -segments are different from each other, even at Lanka, as they are inclined differently to the equator. For the same segment, there is a further change in the inclination due to the latitude of the location. Both these factors contribute to the differences in the rising times of *rāśi*s.

7.0 *ŚAṄKU*

Śaṅku is the central object in the '*tripraśnādhikāra*' of any text and determines the shadow of the Sun at an instant when z is its zenith distance. It is related to the latitude(φ), the declination (δ) and the hour angle, '*naṭa*' (H) or the azimuth *(iśṭāgra).* The smaller of the elapsed time or the time to elapse before Sunset is decreased by the '*carārdha*' when the Sun is in the northern hemisphere and increased by it in the southern hemisphere, and its Rsine is multiplied by the day-radius and divided by the *trijyā* (R). the *kujyā* (*kṣitijyā* or the Earth-Sine) is added to this in the northern hemisphere and subtracted from this in the southern hemisphere is the *Cheda* (called *Hṛti* also by others). The *cheda* multiplied by the *lambaka* (R cosφ) and divided by the radius is the *Śaṅku*.

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