Course 6: Basics of Indian Astronomy

1. Introduction

- The science of Astronomy. Astronomy as one of earliest sciences; observational astronomy in the Vedic corpus. Emergence of Jyotiḥśāstra encompassing the three skandhas of Gaṇita (Astronomy), Horā (Horoscopic Astrology and Saṃhitā (Omens and Natural Phenomena). The purpose of Astronomy—as stated in the texts. Contents of a typical Indian astronomical *Siddhānta* text. Broad classification of the texts in Indian astronomy. Names of some of the prominent astronomers and their important contributions. Highlight the continuity of the Indian astronomical tradition (1400 BCE – 19th cent CE).

2. The different units of time discussed in the texts

- Brief introduction to the concept of time (approach of physics and philosophy). Quote from Bhāskara I's commentary at the beginning of Kālakriyā; also quote the verse in the famous text *Sūryasiddhānta*. Recount the currently used units of time—duration of year, month, week, etc. in the Gregorian calendrical system—subtly point out that they do not have any astronomical basis whatsoever. Introduce the different shorter units of time discussed in Indian astronomical texts year, month, fortnight, *tithi*, etc. Introduce larger units or time like *yuga, mahāyuga, manvantara* and *kalpa*.

3. Systems employed for representing numbers

- Highlight the need for having different systems for representing numbers in those days. Explain the three systems adopted - *Bhūtasaṅkhyā, Kaṭapayādi and Āryabhaṭīyapaddhati*. With illustrative examples, bring out their beauty and ingenuity. Briefly discuss the advantages in each of these systems.

4. Spherical trigonometry

- Introduce the notion of shortest path on a non-Euclidean surface. Definition of great circle, small circle, spherical triangle, etc. Their illustration using the Earth as an example, which the students will be familiar with. Compare and contrast the properties of a spherical triangle with a planar triangle. Derive the cosine and sine formula from 'first' principles. Introduce the four-part formula. Work out a few illustrative problems (such as distance travelled by a flight along the great circle arc, small circle arc, etc) that would help visualise the circles on a sphere, as well as assimilate the application of the formulae. Demonstrate how to derive the sine formula simply using the planar triangles, and their projections inside the sphere.

5. Celestial Sphere

- The notion of celestial sphere and the need for its conception. The different coordinate systems (horizontal, equatorial and ecliptic) employed. The range of the coordinates in each of these systems. The advantages and disadvantages of one system over the other. Some illustrative examples for converting one set of coordinates into another. Indian names for the fundamental circles and the coordinates used in these systems.

6. What is *Pañcāṅga*?

- Division of the celestial sphere/ecliptic into 12 and 27 equal parts — *rāśi* and *nakṣatra* division. Explain their significance by pointing out their basis; that is, they are connected with the duration of 12 lunar months and the period of moon's revolution around the earth, and not introduced arbitrarily. Explain the five elements that constitute *Pañcāṅga* – and also bring out their astronomical significance. Also point out that they are essentially different units of time. Illustrate with numerical examples the computation of these elements in a *Pañcāṅga*. Explain how to compute the average period of a lunar month; Bring out the need for the introduction of an *adhikamāsa* in the calendrical system. Outline the broad categories into which different calendars that are followed can be put into— namely solar, lunar and luni-solar.

7. Key concepts pertaining to planetary computations

- The revolution numbers of various planets, nodes, apogees, etc.; The count of the number of civil days, *adhikamāsas*, etc. in a *mahāyuga*. Introduce the concept of Ahargaṇa, and its significance; The basis for choice of epoch. Calculation of *Ahargaṇa*; Illustration with a few numerical examples choosing contemporary dates – using *siddhāntic* text (to begin with). Explain the computation of mean motion of planets, and how its computation along with the *Ahargaṇa* can help in finding the mean position of planets.

8. Computation of the true longitudes of planets

- Provide an overview of the steps involved in the computation of the true longitudes. Explain *manda-saṃskāra* in detail using epicyclic model and eccentric model. Outline the nature of the resultant orbit, etc, and explain how this correction takes into account the eccentric nature of the planetary orbit. Emphasise and make the students appreciate the simplification achieved in computation by the 'constraint' $r/R = r_0/R$. Explain *śīghra-saṃskāra* in detail; Point out how this correction boils down to the transformation of the heliocentric coordinates to geocentric. Also indicate how this simple model takes care of the retrograde motion of the planets. Bring out the distinction between the inner and outer planets.

9. Precession of equinoxes – *sāyana* and *nirayaṇa* longitude

- Introduce the concept of precession of equinoxes. Explain solsticial and equinoctial points, and connect them to the concept of *uttarāyaṇa* and *dakṣiṇāyana* in the Indian calendrical system. Derive the formula for finding the declination of the sun on any day at any time, and also illustrate it with examples. Also highlight how crucial its accurate computation is for the computation of various other quantities precisely — including the problem of finding the direction and the latitude of the place — even if we choose to do them by experimental methods.

10. Finding the cardinal directions and the latitude of a place

- Introduce *śaṅku* (the gnomon), and explain how it has to be prepared as described in the texts. Describe the experimental set up that has to be made meticulously for conducting experiments with *śaṅku* and doing shadow measurements. Explain how with a very simple experiment the directions at a given place can be easily and precisely determined. Also point out that this experimental method is very old—described even in the *Śulbasūtras*. Also outline the theoretical basis for the formula that has been given for correcting the points marked in connection with determination of the direction using *śaṅku*. Bring out the versatility of this simple device *śaṅku* in determining a variety of physical quantities of interest including the latitude of the place. Explain the concept of parallax in general, and how it introduces an error – that is unavoidable in conducting this experiment for determining the latitude of the place. Outline the corrections that have been prescribed in the text that would take into account the above error, as well as the fact that sun is not a point source of light.

11. Determination of the variation of the duration of the day at a given location

- Introduce the 6'o clock circle and its significance. Derive the formula for the hour angle at sunset, and explain how the latitude and the declination of the sun play a role in it.

Explain the concept of *cara* as outlined in the Indian astronomical texts that captures the variation in the duration of the day at a given location. Present the formula for determining the local time using shadow measurements. Also outline how *cara* plays a role in determining this local time. Bring out the distinction between this local time and the standard time that we are generally familiar with and generally keep track of.

12. *Lagna* and its computation

- Introduce the concept of *lagna*, and how non-trivial a problem it is to determine it precisely. Also point out how this is deeply connected with fixing times for various social and religious functions such as marriage, etc. Bring out the connection between its computation and the computation of declination, *cara* etc. that would have been discussed before. Explain how this can be determined 'reasonably' accurately using interpolation. Also outline more precise formulations that have been given by later astronomers by introducing the notion of *kālalagna*.

13. Eclipses and their computation

- Briefly explain the phenomenon of lunar and solar eclipses, and the crucial role played by the position of the lunar nodes in their computation. Also bring out how difficult it is to precisely determine the position of the nodes—as they are not physical objects available for observation. Explain how the latitude of the moon is computed, and then outline the procedure for the determination of the semi-diameters of the eclipsing and the eclipsed bodies. Derive the simple formula for determining the duration of eclipses as well as the obscuration. Also mention that iterative procedures are followed to improve accuracy. Point out the role of parallax in the determination of solar eclipses.

References:

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   S. Sriram, Hindustan Book Agency, New Delhi 2011.