Course 7: Introduction to Indian Astronomy

SEMESTER I

1. **Preliminaries**
   - Sky viewed as the inside of a hemisphere. Cardinal directions, zenith, horizon, pole star at any location. Daily motion of celestial objects (Sun, Moon, planets, stars) and diurnal circles. Motion in the stellar background. Ecliptic. Basic time units: Day, Month and Year. Celestial coordinates and elementary spherical trigonometry. Cosine and Sine formulae. Horizontal (z,A), Equatorial (δ, α and H), and Ecliptic (λ, β) systems.
     cos z = sin φ sin δ + cos φ cosδ cos H, and other relations. Planetary positions.
2. **Developments from the Vedic period up to the *Siddhāntic* period**
   - *Vedic Astronomy:* Astronomical concepts in Vedic literature regarding Sun, Moon, Stars, Earth. Months, seasons, year. 27 *nakṣatras*. Ecliptic and *ayana*. Planets, Comets etc. Pole star in an earlier era. *Nakṣatra* division of the ecliptic and motion of the Sun along it in *Vedāṅga Jyotiṣa* (VJ) and other texts. VJ calendar. VJ computations. Duration of a day. Better value for an year in Vedic literature.
   - *Siddhāntic astronomy*: Earlier *Siddhāntas* and *Pañcasiddhāntikā*. Introduction of trigonometry, Indian *jyā*–astronomy. *Āryabhaṭīya* . *Mahāyuga*. (*Kalpa* etc., and also smaller units of time can be introduced at this stage). Revolution numbers of planets. *Ahargaṇa* and Mean longitudes, Examples. Obtaining the true longitudes by applying corrections to mean longitudes.
   - Epicycle models: *Manda* correction (Equation of centre) in detail. Its significance. Latitude of Moon.
   - *Śīghra* correction to planets and its significance: Essential features only with the aid of diagrams and final formulae. Latitudes of planets.
     Precession of equinoxes— *Nirayana* and *Sāyana* longitudes.
   - Nature and organisation of texts. *Sūtra* (algorithmic) format. *Siddhānta*, *Tantra*, *Karaṇa* and *Vākya* texts. *Sāraṇis* or Tables.
3. **Indian Calendar**
   - *Pañcāṅga*. *Adhikamāsas*. Solar and Luni-Solar systems.
4. **Solar and Lunar Eclipses**
   - Angular diameters of the Sun, Moon and Earth's shadow. Possibility of eclipses. Finding the middle of an eclipse by iteration. Amount of obscuration at any time.
5. **Tripraśna Topics (Diurnal problems)**

Description of the celestial spheres and various circles. Similarity to modern description. Determination of the East-West directions. Derivation of the expression for the declination in terms of the longitude. Shadow of a gnomon. Equinoctial day when the locus of the tip of the shadow is a straight line. Finding the latitude. Mid-day shadow. Finding the declination. Relation between the time and the shadow at an arbitrary instant (no derivation).

SEMESTER II

1. **Planetary longitudes and latitudes and Nīlakaṇṭha Somayājī's revised planetary model**
   - True longitudes of planets: *Manda* and *Śīghra* corrections in detail. Geometrical description. Comparison with Kepler's model. Latitudes of planets.
   - Nīlakaṇṭha Somayājī's revision of the planetary model: Nīlakaṇṭha's analysis of the motion of the interior planets (Mercury and Venus). His geometrical model which is geometrically similar

to the Tycho Brahe model (planets moving around the Sun which itself orbits the Earth), but computationally approximates the Kepler model.

2. **Rates of motion of planets**
   - Idea of derivative in finding the *Mandagatiphala* (*manda*-correction to the mean rate of motion). The correct formula due to Nīlakaṇṭha. True rates of motion of planets: Correct expression due to Bhāskara. Application to calculate retrograde motion of planets.
3. ***Tripraśna* topics**
   - Latitudinal triangles (of Bhāskara) and applications. *Agrajyā* or the distance between rising-setting line and the east-west line. Correction to the east-west line due to change in Sun's declination. Zenith distance in terms of the declination, hour angle and latitude ($\cos z = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos H$). Derivation of this formula as in S*iddhāntaśiromaṇi*. Relation among *Śaṅkutala* (*Śaṅkvagra*), *Bhujā*, *Agrajyā* and its applications.
4. **Rising times of *Rāśis* and finding *Lagna***
   - Relation between the right ascension and longitude and rising times of *rāśis* at the equator. Rising times at an arbitrary latitude. Finding the *Lagna* at any instant after Sunrise (approximate).
5. **Eclipse calculations**
   - Details of calculations of the middle of a lunar eclipse and half-durations iteratively, using the correct expression for the rate of motion of the Moon. Parallax and the calculation of the middle of a solar eclipse.
6. **The *Vākya* system**
   - Longitude of the Sun from the 'subtractive minutes' at any time ('*Bhūpajña* etc. *vākyas*). *Vākyas* for zodiacal transit times ('*Śrīrguṇamitra*' etc.). Longitude of the Moon using the *Candravākyas* ('*gīrnaśreyaḥ*' etc). More accurate values due to Mādhava.
7. **Astronomical Instruments**
   - Gnomon . *Cakra* and *Dhanur* yantras for measuring the zenith distance of the Sun. Approximate and exact times from a '*yaṣṭi*'. *Phalakayantra* to measure the hour angle. Equatorial sundial to measure time. Clepsydra for measuring time. Celestial globe and Armillary sphere for explaining celestial coordinates and various circles.
8. **Indian Astronomy in the 18th and 19th centiries**
   - Astronomical endeavours of Savai Jayasiṃha. *Samrat-yantra* and other instruments in the observatories of Jayasiṃha. European observers on the simplicity and accuracy of Indian eclipse computations. The work of Śaṅkaravarman and Candraśekhara Sāmanta. Efforts to update the Indian calendar.

References

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(Videos available at https://www.youtube.com/watch?v=Qzam3vEnD-8&list=PLF72fmBZVDxlkv0Ih_aSHnax5S5-wug8v)
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4. S. Balachandra Rao, *Indian Astronomy-Concepts and Procedures*, M.P. Birla Institute of Management, Bengaluru, 2014.
5. K. Ramasubramanian, A. Sule and M. Vahia, Eds. *History of Astronomy: A Handbook*, SandHI, I.I.T Bombay, and T.I.F.R., Mumbai, 2016.
6. *Āryabhaṭīya of Āryabhaṭa*, Edited with translation and notes, K. S. Shukla and K.
V. Sarma, Indian National Science Academy, New Delhi, New Delhi, 1976.
7. B.V. Subbarayappa and K.V. Sarma, *Indian Astronomy: A Source Book*, Nehru Centre, Bombay, 1985.
8. *Tantrasaṅgraha of Nīlakaṇṭha Somayājī*, Translation and Notes, K. Ramasubramanian and
M.S. Sriram, Hindustan Book Agency, New Delhi and Springer, 2011.
9. *Karaṇapaddhati of Putumana Somayājī*, Translation and Notes, R. Venkateswara Pai, K. Ramasubramanian, M.S. Sriram and M. D. Srinivas, Hindustan Book Agency, New Delhi and Springer, 2018.