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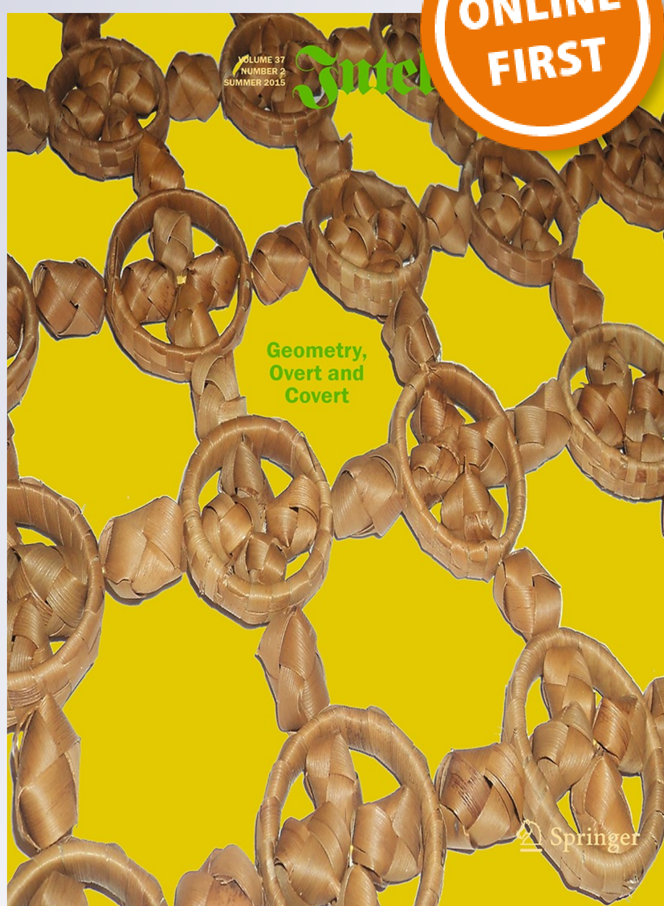

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The Siddhānta-sundara of Jñānarāja: An English Translation with Commentary

by Toke Lindegaard Knudsen

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REVIEWED BY JAYANT SHAH

The tradition of geometric astronomy in India, from Āryabhata (c. 500 CE) to Nīlakaṇṭha (c. 1500 CE), is based on the pre-Ptolemaic Greek astronomy that was introduced in India sometime early in the first millennium. Thus the basic framework of the Indian astronomy was single epicycle models for the Sun and the Moon and models with two epicycles for the planets. Menelaus's spherical trigonometry was unknown. Indian astronomers derived the necessary formulae for handling spherical geometry from a set of basic plane right triangles. With the exception of the introduction of lunar evection by *Mañjula* in the 10th century, this framework remained unchanged throughout the development of Indian astronomy. Although Greek astronomy arrived in India, Greek tradition did not. Indian astronomers followed the tradition of *Pāṇini*, *Piṅgala*, and *purāṇas* as they sought to refine and adapt the Greek import. There is an increasing degree of sophistication culminating in *Mādhava's* power series and *Nīlakaṇṭha's* implicitly heliocentric models for the inferior planets. At the same time, there are approximations and tables for everyday religious and astrological calculations. Even though many important Indian astronomical manuscripts have been translated, our understanding of the Indian tradition remains incomplete. Many manuscripts still remain to be explored and translated. The translation of Jñānarāja's *Siddhāntasundara* by Toke Lindegaard Knudsen is a welcome addition. It is to be hoped that as more manuscripts are studied, a more complete picture will emerge.

Medieval Indian astronomical literature falls into three distinct genres: Comprehensive treatises (*siddhānta*s and *tantra*s), Manuals (*karaṇa*s) containing simplified algorithms, and Tables (*koṣṭhaka*s) ready for use by astrologers and calendar makers. As its name indicates, *Siddhāntasundara* belongs to the first category. These texts expound formulae and algorithms for solving a typical sequence of problems in astronomy. Some are more wide-ranging than others, covering topics in arithmetic, algebra, and even prosody, often with no apparent application. As usual these texts are written, as are a lot of Indian technical texts, in terse Sanskrit verses. Brevity and rules of prosody imposed constraints. Writers not only used several synonymous terms to indicate a particular concept, but also sometimes used the same term to mean different concepts depending on its context. The result is to render the task of translation a major undertaking. Teasing out the true meaning from a corrupted text is exceedingly difficult.

Siddhāntasundara is one of the two major *siddhānta*s composed after the monumental *siddhāntaśiromaṇi* of Bhāskara II (c. 1150 CE), the other being Nīlakaṇṭha's *Tantrasaṅgraha* composed at about the same time as *Siddhāntasundara* (c. 1500 CE). The two *siddhāntas* offer a study in contrast. While Jñānarāja is preoccupied with reconciling the ancient Indian cosmology of *vedas* and *purāṇas* with Hellenistic astronomy, his contemporary 900 miles to the south, Nīlakaṇṭha, is introducing mathematical innovations and refining planetary models. Consequently, Jñānarāja divides his treatise into two parts. He devotes the first part to the cosmology of *purāṇas* and tries to reconcile it with the Hellenistic astronomy of *siddhāntas*. The second part follows a typical sequence of traditional topics in Indian mathematical astronomy with frequent digression to *purāṇas*.

Siddhāntasundara is not easy to follow. Topics do not always follow a logical progression. Chapter contents are not unified. Jñānarāja routinely uses technical terms in his preliminary discussions before these terms are defined in detail in a later chapter. Knudsen's introductory chapter and commentary provide a helpful guide. He has done an admirable job of providing cross-references to navigate through Jñānarāja's exposition. Despite his best efforts, the mathematical content of some of the verses remains obscure.

The book is organized as follows:

Introduction

An introduction to Indian astronomy, a brief description of the cosmology of *purāṇas*, an overview of *Siddhāntasundara*, and a discussion of Jñānarāja's place and time.

Part I: General Description

1. Lexicon of the Worlds: Jñānarāja starts by pointing out that *jyotihśāstra* (science of luminaries) is one of the six limbs of *vedas* (*vedāṅgas*). It includes three divisions: astronomy, astrology, and omens. Three different accounts of creation are recounted. Earth's sphericity is reconciled with the *purāṇa's* geography of seven ring-shaped oceans. This is followed by terrestrial geography and cosmology.
2. Rationale of Planetary Motion: Planetary motions are qualitatively described. The reader is assumed to be generally familiar with technical terms such as latitudes, declination, nodes, apogee, epicycles, and so on. Different measures of year, month, and day are provided.
3. Method of Projections: The theoretical framework of planetary models is explained in terms of the eccentric circle as well as the epicycles.
4. Description of the Great Circles: Great circles defined by the three coordinate systems, ecliptic, equatorial, and

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horizontal, are described. These are fundamental to the Indian method of astronomical calculations.

5. Astronomical Instruments: Jñānarāja lists seven different instruments, but describes in detail only one of them, namely, the sine-quadrant. In essence, it is a device to read off values of sine graphically. It also has sighting vanes. A number of applications are provided, but descriptions are not entirely clear.
6. Description of the Seasons: This is a nontechnical description of the six seasons in a year. The poetic description more appropriately belongs to the tradition of the poet and playwright Kālidāsa (4th or 5th century CE) rather than astronomy. Jñānarāja uses the technique known as *śleṣa* so that each verse has two narratives. Either it can be read as some story from Indian mythology or it can be seen as the description of a season.

Part II: Mathematical Astronomy

1. Mean Motions: The traditional great periods are listed. A *kalpa* consists of 4,320,000,000 sidereal years, divided into smaller periods, *mahāyugas* and *yugas*. Planets, nodes, and apogees make a whole number of revolutions around the earth in a *kalpa*. All the planets, nodes, and apogees are postulated to be at the zero-degree longitude when the planetary motion begins. A procedure for calculating the number of elapsed years up to the start of the *śaka* era (78 CE) is presented. From these data, one can calculate the mean longitudes at any given time. Jñānarāja now proceeds to describe an approximate method for checking the theoretical mean motion by means of observations. Next a more practical method is provided for calculating the mean longitudes from their values at epoch *śaka* 1425. Finally, a formula for longitudinal correction for places not on the prime meridian is provided.
2. True Motions: Mean motions are corrected by taking into account the geometry of the actual orbits based on eccentric and epicyclic models. The chapter begins with a table of sines. As usual in Indian astronomy, epicycles have variable radii. Jñānarāja shows a method for computing square roots, which is the same as the method given by Heron of Alexandria (c. 1st century CE) and apparently recorded here for the first time in an Indian treatise. Jñānarāja follows the Indian tradition of using a multistep procedure for combining the contributions of the two epicycles in the case of the star-planets. Jñānarāja's omission of lunar evection is perhaps indicative of his relative priorities. A formula for the ascensional difference is provided for use in computing the lengths of days and nights. The chapter ends with a procedure for calculating the ascendant.
3. Three Questions: This is the traditional title of a chapter discussing locally observed astronomy and refers to direction, place, and time. A procedure for determining the cardinal direction by means of a gnomon is described. Eight plane right triangles involving various coordinate circles are introduced and form a basis for deriving the formulae for local astronomical phenomena. The mathematical meaning of a lot of verses remains unclear.
4. Occurrences of Eclipses: Methods for computing quantities related to eclipses are presented. Much of the material in this chapter is repeated in the individual chapters on lunar and solar eclipses that follow.
5. Lunar Eclipses: Apparent diameters of the Moon, the Sun, and the earth's shadow at the distance of the Moon are computed. From the lunar latitude at the time of conjunction, the magnitude of the eclipse is obtained. A procedure for calculating the angle between the ecliptic and the east-west line on the Moon's disk is given.
6. Solar Eclipses: Solar eclipses are more complicated to predict because of the lunar parallax. Approximate formulae of Jñānarāja for computing the zenith distance of the nonagesimal are the same as in *Sūryasiddhānta*. After computing the longitudinal parallax, the time of apparent conjunction is obtained by an iterative procedure. From the lunar latitude corrected for the latitudinal parallax, the magnitude of the eclipse is obtained. At the end of the chapter, the rationale for the formulae is briefly explained.
7. Rising and Setting of the Planets: Limits on elongation of a planet to be visible are given and then corrected for the true latitude of the planet.
8. Shadows of Stars: Shadows of planets are to be found just as in the case of the Sun. Polar longitudes and latitudes of *Nakṣatras* (constellations) and positions of the seven stars of Ursa Major are given.
9. Elevation of Lunar Horns: The objective is to determine the shape and orientation of the lunar crescent with respect to the cardinal directions. The meaning of some of the verses is unclear.
10. Conjunctions of Planets: This brief chapter calculates the time of conjunction in a straightforward manner from the true positions and true velocities of the planets.
11. *pātas*: These are astrologically inauspicious events that depend on the relative positions of the Sun and the Moon.

Siddhāntasundara is of interest perhaps mostly to experts, but Jñānarāja's efforts to defend the *purāṇa's* cosmology is of general interest. The book does not include the Sanskrit text, but the author plans to publish a critically edited Sanskrit text in the future. *Siddhāntasundara* provides an important link in the multifaceted development of the Indian astronomy after Bhāskara II. As the author points out, the next step is a detailed analysis of its sources and its influence on the subsequent development of astronomical thought in India.

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