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BOOK REVIEW

S. Balachandra Rao, ***Ancient Indian Astronomy - Planetary Positions and Eclipses***, B R Publishing Corporation, Delhi, 2000, 288 pages, Rs. 1200.

This is an interesting publication in history of ancient Indian astronomy. It is based mainly on three texts viz. the *Khaṇḍakhādyaka* of Brahmagupta (628 AD) *Sūryasiddhānta* (850 AD) and *Grahalāghava* of Ganeśa Daivajña (1520 AD), the first and the third being karaṇa texts and the second one is a siddhantic work.

The volume has in all 14 chapters, 2 appendixes, bibliography and glossary of technical terms.

The first four chapters deal with short historical survey, zodiac and constellations, co-ordinate systems, yuga system and eras, and are useful for preliminary information. There was actually three types of astronomical works viz. siddhantic texts following an epoch from the beginning of Kalpa, the *tantra* texts having an epoch from a convenient year. According to *Sūryasiddhānta,* a *Kalpa* is a period of 1000 *Mahāyugas*. The *Mahāyugas* consists of a period of 4320000 years, and was again made of four smaller peiods - *kṛta, tretā, dvāpara* and *kali* in the ratio 4:3:2:1. This shows that the *Mahāyuga* is 10 times of the *kaliyuga* having a period of 432000 years. The *kaliyuga* again is supposed to have commenced at the midnight of 17-18 February, 3102 BC (*ardharātrika* system), or morning of Friday, February 18, 3102 BC (*audayika* system) by Julian reckoning.

The chapters 5 and 6 give the working methods as to how to find the number of civil days (*ahargaṇa*) for a required date with reference to an epoch, and the mean position of planets for the date. In this connection it is interesting to note that the Indian astronomical texts followed a luni-solar system and has supplied parameters like sidereal revolutions of planets (Sun, Moon, Moon's apoge, Moon's node, Mercury, Mercury's *śighrocca*, Venus, Venus's *śighrocca,* Mars, Jupter and Saturn), civil days (*sāvanadina*), lunar days (*tithis*), intercalary months (*adhimāsa*), omitted *tithis* (*kṣaya* or *abamadina*) etc. in a *Kalpa* or *Mahāyuga*. How these elements, which are surprisingly correct and modified from time to time, were obtained are not very clearly known, though there are various conjectures. The methods of calculating *ahargaṇa* are more or less similar and the readers may also see my article in this context, vide *IJHS* 38.1 (2003), 17-37. Once the *ahargaṇa* for a date is known, it is then multiplied by the mean daily motion of planet to obtain the mean position of planet for the date. This when added to epochal position gives the mean position of planet at sunrise in Ujjain, since Ujjain was considered the prime meridian of Indian subcontinent.

The chapter 7 deals with the method for finding true longitude of Sun and Moon from its mean position at Ujjain to local meridian. The Siddhantic texts recognised two corrections viz. *deśāntara* (longitude correction), *mandaphala* (due to Sun's equation of centre) for Sun and Moon. However two more corrections namely *bhujāntara* (due to eccentricity of the Earth's orbit), and *cara* (or *udayāntara* correction due to Sun's ascensional difference) were also recommended. The *deśāntara* correction was carried out to correct the mean position from Ujjain meridian to local meridian. This occurs due to the earth's rotation at the rate of 360° per day of 24 hours, or 6° per *ghaṭikā*. The difference of longitude or time difference was added to or substracted from for any place towards east or west of Ujjain time. The *mandakendra* (mean anomaly) occurs because the ancients observed the variation between mean and true positions but could not conceive an elliptical orbit for planets with Sun in one of its focii, rather they conceived two models, viz. i) the mean Sun is moving around the Earth in a deferent, and the true Sun and other planets moving round the mean Sun in a variable epicycle with mean Sun moving on the deferant with uniform circular motion as that of the planets (epicyclic model), and ii) the centre of the celestial sphere coincides with the centre of Earth but it is little away from it, and this distance is more or less equal to the radius of the epicycle (excentric model). In both the models, *mandaphala* is given as r(R Sin m)/R, where m = *mandakendra* (mean anomaly), r = radius of the epicycle and R = radius of the deferent. When it is less than 180°, the true Sun is behind the mean Sun; and when greater than 180°, the true Sun is in advance of the mean Sun. Hence the *mandaphala* is substrative or additive according as Sun's *mandakendra* is in the half orbit beginning with Aries or Libra respectively. This correction gives the Sun's true longitude for mean sunrise at the *svanirakṣa* place. The *bhujāntara* correction for the Sun was suggested since true midnight of the place differs from the mean midnight. It was obtained by multiplying the equation of centre in degrees by daily motion of the planet in minutes and divided by 21600. This was added or substracted according as the *mandaphala* is additive or substractive. The *cara* correction for Sun occurs because of the obliquity of the ecliptic with the equator which rectifies the sunrise and sunset time. It is a fact that in the northern hemisphere, sunrise at the local place occurs earlier and sunset later than the *svanirakṣa* place, and for southern hemisphere it is opposite. It was obtained by multiplying the eccentricity of the Earth by daily motion of the planet in minutes and divided by 21600. This correction rectifies the Sun's true longitude of the *svanirakṣa* place sunrise to Sun's true longitude at true sunrise at the local place. The correction were recommended by *Bhāskara* I, Śripati, Bhāskara II and others.

For Moon, the same four corrections were applied. However, a few more corrections were also recommended. The correction for Moon, carried out alongwith the equation of the centre, is defined as the deficit in the equation of the Moon plus the inequality of the motion of the Moon due to variation of the eccentricity of the orbit (known as evection). To appreciate, let us consider the modern value and the relevant terms of the Moon's longitudes and it is given by:

Moon's true longitude (λ) = M - equation of the centre - evection = M - 377′.3 Sin g - 76′.4 Sin (2D-g), where g = M-U = angular distance between mean Moon and its apogee, and D = M-S = angular distance between Mean Moon and Mean Sun.

$$\begin{aligned} \text{or, } \lambda &= M - (300'.9 + 76'.4)\ \text{Sin } g - 76'.4\ \text{Sin } (2D-g) \\ &= M - 300'.9\ \text{Sin } g - 76'.4\ [\text{Sin } (2D-g) + \text{Sin } g] \\ &= M - 300'.9\ \text{Sin } g - 76'.4\ .2\text{Sin } D.\ \text{Cos } (D-g) \\ &= M - 300'.9\ \text{Sin } g - 152'.8\ \text{Sin } D.\ \text{Cos } (D-g) \\ &= M - \mu_1 \text{Sin } g - \mu_2 \text{Sin } D.\ \text{Cos } (D-g) \end{aligned}$$

Indian system gave almost the same reduced expression for Moon in which the coefficient of μ_1 (equation of centre) and μ_2 (evection) are closer to 300′.9 Sin g and 152′.8 rather than the original values 377′.3 Sin g and 76′.4 respectively. This shows that Indian values of evection contains some portion of the equation of the centre. Actually, values of μ_1 are 300′.25 (*Āryabhaṭīya*), 296′ (*Khaṇḍakhādyaka*) and 293′.5 (*Brāhmasphutasiddhānta*) and μ_2 as 144′ (Vaṭeśvara and Muñjāla), 160′ (Śrīpati and Candraśekhara Sāmanta) and 171′.9 (Nīlakaṇṭha) as given in Indian works.

Bhāskara II recommended another inequality for Moon, now known as variation, which is due to the attraction of the Sun on the Earth-Moon system during a synodic month. The modern value is 39′.5 Sin 2D while the value given by Bhāskara II was 34′ Sin 2D.

There is another inequality for the Moon's annual motion which is due to annual variation of the Earth's distance from the Sun, being greatest at the aphelion and least at the perihelion (*annual equation*). The modern value is +11′.2 Sin g, where g is the angular distance of the mean Sun from the apogee. Candrasekhar Samantha gives the correction as 11′ 27″.6 Sin g.

Hence $\lambda = M - 300'.9 \text{ Sin g} - 152'.8 \text{ Sin D.Cos (D-g)} + 39'.5 \text{ Sin 2D} + 11'.2$ Sing g (modern).

and $\lambda = M - 300'.25 \text{ Sin g} - 144' \text{ Sin D. Cos (D-g)} + 34' \text{ Sin 2D} + 11' 27''.6$ Sin g (Indian). The Indian results are quite praiseworthy.

When D = 0° or 180°, the 2nd and 3rd and 4th terms vanish, that means when it is new moon or full moon, only the first term of the inequalities come into play. Traditional *pañcāṅga* makers are often at fault when they take only the first inequality. Madhāva (1400 AD) gave nine anomalistic cycle of 248 days and the difference in longitude in *candravākyas* from zero at Sunrise which are astonishingly correct.

The chapter 8 gives the traditional method for correcting daily motions of the Sun and Moon, useful for finding time for instant conjunction and opposition.

The chapter 9 and 10 deal with lunar and solar eclipses, and explain the role of opposition and conjunction of Sun and Moon and the proximity of the Moon near its node as plausible causes for lunar and solar eclipses. To calculate the duration, magnitude, the first, last and middle contacts and other parameters namely true longitude of Sun, Moon, Moon's node, true daily motion of these three bodies, latitude of the Moon, angular diameters of the Earth's shadow and of the moon, *lambana* (parallax in longitude), *vikṣepa* (parallax in latitude) etc. were exemplified with examples as per specified texts.

The Chapter 11 and 12 deal with the mean and true position of star planets. As for planets Mercury, Venus, Mars, Jupiter and Saturn which revolve round the Sun, besides the normal corrections as applicable for Sun, two kinds of epicycles namely *manda* and *śighra* were envisaged. Since epicycles stated in these texts correspond to the beginning of the odd and even anomalistic quadrants, their values at other positions of the planets are derived by the rule of three. It is believed that they are the mean epicycles corresponding to the mean distances of the planets. In order to obtain the correct epicycles, Āryabhaṭa I and the *Sūryasiddhānta* unlike that of Ptolemy who had a fixed epicycle on which the true mean planet is supposed to move, used a formula for correct *manda* epicycle = true *manda* epicycle x H/R, where H is the planet's true distance in minutes obtained by the process of iteration (*asakṛtkarana*). For *śighra* epicycles, however the corrected epicycles are the same as the true epicycles. *Āryabhaṭa* I and other *Siddhantic* astronomers found that the true longitude of the planet thus obtained from the mean longitude differs in observations. Accordingly, the error, he thought that was due to inaccuracy of the *mandakendra* (mean anomaly), and to rectify the error, he applied in succession i) half the planets' *mandaphala* and ii) half the planets' *śighraphala* to the *mandakendra* for superior planets (Mars, Jupiter and Saturn), and half the planets *sighraphala* to the *mandakendra* for the inferior planets. These corrections were applied in succession. Bhaskara II also noticed that the divergence between the computed mean position and the true poition was minimum when these planets were in conjunction or in opposition with the Sun, and guessed that the Sun was playing a part in this divergence. He further observed that Mercury and Venus were found to be in oscillation about the mean position of the Sun, where as other planets Mars, Jupiter and Saturn were going round the Sky, thus a differentiation was made with Mercury and Venus in one group and the other superior planets in another. For Mercury and Venus, their elongation becomes the *śighraphala* which is to be added or substracted from the Sun's mean position to get their geocentric positions. In case of Mars, Jupiter and Saturn, their mean positions construd unknowingly as geocentric are indeed heliocentric, and the mean geocentric sidereal period will be the same as the mean heliocentric sidereal period for the simple reason that the Earth's orbit is contained within the orbits of these planets. Nīlakaṇṭha (1450 AD) tried to unify the differential method applied to the inferior and superior planets and in fact suggested a common centre for the *śighra* equation of all planets. This was indeed a remarkable break through in history of mathematical astronomy in general and Indian astronomy in particular.

Chapter 13 has incorporated some *bija* corrections on the traditional method of eclipses as suggested by T S Kuppanna Sastry to improve further the timings of eclipses deviated through centuries. Chapter 14 suggests improvement of the main parameters (*bija* corrections) in view of the fact that they are valid only for a century or so. This is carried out following traditonal systems for corrections of parameters, as are done by scholars like Parameśvara, Nīlakaṇṭha and others. Here the author has suggested the changes in parameters like revolution of plants in Mahayuga, peripheries of manda epicycles, earth's eccentricity and coefficients of Sun's *manda* equation, peripheries of epicycles, heliocentric distances of planets etc. Toward the equation, peripheries of epicycles, heliocentric distances of planets etc. Toward the end the author has also included an improved algorithm for use in computer programme in order to get comparable data in modern form.

The most important feature of the book is that the procedure and algorithm involved have been explained with examples and their solutions. The use of traditional terms and abbreviations at time has made the book little complex in the absence of modern symbols and uniformity, but on the whole it is quite useful for students and research scholars. The examples as worked out are found to be consistent. To show the importance of the methodology he has many a times taken data from modern tables - a deviation which is not in line with historiocity. Inspite of limitations the book achieves its goal to a great extent and may be recommended undoubtedly as a text book on history of Indian astronomy. We are thankful to the author for presenting to us such a nice publication.

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