# 3.2 SYSTEM OF ASTRONOMICAL CONSTANTS IN HINDU ASTRONOMY

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Abstract: Astronomical constants such as the length of the solar year, sidereal and synodic periods of revolutions of the Moon and five brighter planets have been computed using the system of astronomy in ancient and mediaeval India and a comparison made with their modern values. The modern values of the Moon's inequalities have been compared with that of the earlier Hindu astronomical reckonings. Also, the Equation of the Centre of the Sun as determined in the period 500 A.D. to 1150 A.D. has been discussed in relation to corresponding modern values.

## INTRODUCTION

S.B. Dikshit (1968) has divided the entire history of Indian Astronomy into three periods viz. (1) The Vedic period, (2) The Vedāṅga period and (3) The Siddhāntic period.

In the Vedic period the study of Astronomy does not appear to have been taken up as an independent science. But it appears that some kind of a luni-solar calendar was in use in this period. The year was solar and consisted of 12 lunar months with the inclusion of 13th intercalary month when necessary. The year had 360 days in it. The natural means of measuring a year used to be one complete cycle of the seasons, the number of which used to be six (sometimes five). Spring used to be the first season. Vedic people were able to realise that Moon's period of revolution was shorter than 30 days, and used a primitive luni-solar calendar. The months were lunar, ending on full moon day. Stars and star groups were called *nakṣatra*.

The *Vedāṅga-Jyautiṣa*, belonging to the *Vedāṅga* period, is the earliest work on Indian Astronomy. This work gives rules for framing a five-yearly calendar on the basis of mean motions of the Sun and the Moon. The months ended with a new moon and the Astronomical elements derived from this work are as follows:

| | |
|---|---|
| Average length of the year | 366 days |
| Lunar month (a lunation) | 29.516 days |
| Moon's sidereal period | 27.313 days |

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These elements are very crude. The error in lunar months would accumulate to about 1 day in 5 years whereas it will be about 4 days in 5 years in case of solar months. The solar measure is less accurate than the lunar one, perhaps because the stars near the Sun are never visible for direct observations.

The *Siddhāntic* period was heralded by the works of Āryabhaṭa I, who was born in 476 A.D. and wrote two books on Astronomy viz *Āryabhaṭīya* and a *Tantra*. The former reckoned the day from sunrise and the latter from midnight. A large number of works on Astronomy were written during this period. The following table gives the names of the notable astronomers and their works along with the years of their composition.

TABLE 1:
ASTRONOMERS OF THE *Siddhāntic* PERIOD AND THEIR WORKS.

| | | |
|---|---|---|
| Āryabhaṭa I | *Āryabhaṭīya* and another *Tantra* | 499 A.D. |
| Lāṭadeva | Expounder of *Romaka* and *Pauliśa Siddhāntas* | 505 A.D. |
| Varāhamihira | *Pañca-Siddhāntikā* which includes the *Sūrya-Siddhānta* | c. 550 A.D. |
| Brahmagupta | 1. *Brāhma-Sphuṭa-Siddhānta*<br>2. *Khaṇḍakhādyaka* | 628 A.D.<br>665 A.D. |
| Lalla | *Śiṣyadhīvṛddhida* | 748 A.D. |
| Vaṭeśvara | *Vaṭeśvara-Siddhānta* | 904 A.D. |
| Muñjāla | *Laghumānasa* and *Bṛhanmānasa* | 932 A.D. |
| Śrīpati | *Siddhāntaśekhara* | 1039 A.D. |
| Bhāskara II | *Siddhāntaśiromaṇi* | 1150 A.D. |

SIDEREAL AND SYNODIC PERIODS

Table II gives a comparative study of the sidereal and synodic periods of the Sun, Moon and the Planets as given by the various astronomers of the Siddhāntic period. The astronomers of ancient India were successful in determining the synodical periods of the planets with a greater degree of accuracy than in their determination of the sidereal periods. In the case of the Moon, however, the Indian astronomers were successful in their determination of the value of the lunar month which is now found to be correct within a fraction of a second, although the true position of the Moon shows a great divergence, which is mainly due to their neglecting the additional corrections of Muñjāla and Bhāskara.

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## MOONS MOTION:LUNAR INEQUALITIES

The modern value of the Moon's inequalities up to the first five terms is stated as

| | |
|---|---|
| $+377'.3 \sin g' + 12'.8 \sin 2g'$ | Equation of centre |
| $+ 76'.4 \sin(2D-g')$ | Evection |
| $+ 39'.5 \sin 2D$ | Variation |
| $- 11'.2 \sin g$ | Annual Equation |

where g' and g are the mean anomalies of the Moon and the Sun measured from their respective perigees, and D is given by "mean Moon - mean Sun".

The above expression with the three principal terms may be put into the form

$$-300'.9 \sin g_1 - 152'.8 \cos(D-g_1) \sin D + 39'.5 \sin 2D$$

where $g_1$ being measured from the apogee is given by $g'+180^{\circ}$. In the earlier Hindu astronomical reckonings, we come across only the first term of the above lunar inequalities. But when we come down to the time of Muñjāla (932 A.D.), we get the term of the second inequality in the form

$$-144' \cos(☾ - \alpha) \sin D,$$

Where α stands for the lunar apogee. This, it will be seen, is exactly the modern form of the evection as combined with a part of the equation of apsis shown above. Śrīpati also tried to express the second inequality after the manner of Muñjāla but his constant is equal to 160' instead of Muñjāla's 144', while the correct value is 153'. The third inequality of the Moon known as 'Variation' was used by Bhāskara II alone, his constant being 34' instead of 40' which is taken to be the correct value. The orthodox almanac makers of India, most of whom follow only the *Surya-Siddhanta* for their calculations, do not take account of any of these corrections except the first term, viz., $-300'.9 \sin g_1$ in finding the Moon's place. As a result they are giving in their almanacs the positions of the Moon which often differ from the actual position by as much as 3 degrees of arc (or about 6 hours in time). It is, however, interesting to note that the additional terms of both Śrīpati and Bhāskara vanish when D equals $0^{0}$ or $180^{0}$, which means that at new Moon and full-Moon the position of the Moon is given rather correctly by the above mentioned first term only, except for the residual discrepancy caused by the 'annual equation' which also appears to have been compensated at syzygies by amalgamating the term with the 'equation of centre' of the Sun as shown below.

## EQUATION OF CENTRE OF THE SUN

As regards the equation of centre of the Sun, the modern value of its principal term is $115'.2 \sin g$; in 500 A.D. it was $119'.1 \sin g$, slightly greater than its present value. The corresponding term

TABLE II.

SIDEREAL PERIODS IN DAYS

| Planet | ARB | BS | KK & SSV | VS |
|---|---|---|---|---|
| Sun | 365.258681 | 365.258438 | 365.258750 | 365.258694 |
| Moon | 27.321672 | 27.321667 | 27.321674 | 27.321670 |
| Mercury | 87.96988 | 87.96992 | 87.96999 | 87.96971 |
| Venus | 224.69814 | 224.69794 | 224.69818 | 224.69853 |
| Mars | 686.99974 | 686.99793 | 686.99987 | 686.99857 |
| Jupiter | 4332.27217 | 4332.24009 | 4332.32058 | 4332.31992 |
| Saturn | 10766.06465 | 10765.81524 | 10766.06670 | 10765.77125 |
| Moon's apogee | 3231.98708 | 3232.73410 | 3231.98769 | 3232.09313 |
| Moon's asc.node | 6794.74951 | 6792.25396 | 6794.75080 | 6794.39868 |
| | SSN | SSN with bija corrections | PTM | MOD |
| Sun | 365.258756 | no change | 365.246667 | 365.256363 |
| Moon | 27.321674 | no change | 27.321667 | 27.321661 |
| Mercury | 87.96970 | 87.96978 | 87.96935 | 87.96926 |
| Venus | 224.69857 | 224.69895 | 224.69890 | 224.70080 |
| Mars | 686.99749 | no change | 686.94462 | 686.97985 |
| Jupiter | 4332.32065 | 4332.41581 | 4330.96064 | 4332.58892 |
| Saturn | 10765.77307 | 10764.89172 | 10749.94640 | 10759.22653 |
| Moon's apogee | 3232.09367 | 3232.12016 | 3231.61655 | 3232.58853 |
| Moon's asc.node | 6794.39983 | 6794.28281 | 6796.45587 | 6793.45994 |

SYNODIC PERIODS IN DAYS

| Planet | ARB | BS | KK & SSV | VS |
|---|---|---|---|---|
| Moon | 29.530582 | 29.530582 | 29.530587 | 29.530583 |
| Mercury | 115.87833 | 115.87843 | 115.87852 | 115.87803 |
| Venus | 583.89746 | 583.89675 | 583.89758 | 583.90008 |
| Mars | 779.92103 | 779.92225 | 779.92117 | 779.92260 |
| Jupiter | 398.88950 | 398.88948 | 398.88917 | 398.88911 |
| Saturn | 378.08595 | 378.08599 | 378.08602 | 378.08632 |
| Moon's apogee | 411.79741 | 411.78498 | 411.79749 | 411.79571 |
| Moon's asc.node | 386.00899 | 386.01677 | 386.00906 | 386.01013 |
| | SSN | SSN with bija corrections | PTM | MOD |
| Moon | 29.530588 | no change | - | 29.530588 |
| Mercury | 115.87801 | 115.87815 | 115.8786 | 115.87748 |
| Venus | 583.90018 | 583.90277 | 584.0 | 583.92137 |
| Mars | 779.92427 | no change | 779.9428 | 779.93610 |
| Jupiter | 398.88918 | 398.88837 | 398.8864 | 398.88405 |
| Saturn | 378.08639 | 378.08747 | 378.0930 | 378.09190 |
| Moon's apogee | 411.79578 | 411.79535 | - | 411.78470 |
| Moon's asc.node | 386.01020 | 386.01058 | - | 386.01056 |

Abbreviations

| | | | |
|---|---|---|---|
| ARB | *Āryabhaṭīya* | VS | *Vaṭeśvara Siddhānta* |
| BS | *Brahmasphuṭa Siddhānta* | SSN | *Sūrya-Siddhānta (New)* as available at present |
| KK | *Khaṇḍakhādyaka* | | |
| SSV | *Sūrya-Siddhānta* as known to Varāhamihira | PTM | Ptolemy |
| | | MOD | Modern |

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of the Indian astronomers is, however, 131' sin g, which, as is apparent, does not compare favourably with the correct value. But when we take that the Indian Astronomers were more interested in correctly determining the difference between the longitudes of the Sun and the Moon particularly at new-Moon and full-Moon, it is possible to find out an explanation for the above discrepancy. Taking the values depending on g only in the solar and lunar inequalities, it is observed that

$$\odot - ☾ = 119'.1 \sin g - (-11'.6 \sin g) = 130'.7 \sin g$$

which is exactly the value adopted by the Indian astronomers.

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## DISCUSSION

**S.D.SHARMA** (Comment) : David Pingree has claimed that Munjal's correction is Arabic. Since the Equations of Centre of Indian Tradition are of different origin and were computed using two eclipses with sun at its apogee and moon at $90^0$ from its Apogee and vice versa. The correction by Munjal is a hybrid of 1st equation of centre of moon of Indian tradition; it cannot be of Arabic origin as Arabs used $2^0 23'$ as equation of the centre for sun. This is found to have been used by Almijisti. Note that sun's equation in Indian tradition has annual variation subtracted from it $1^0$ 55' - (-15') = $2^0$ 10'.

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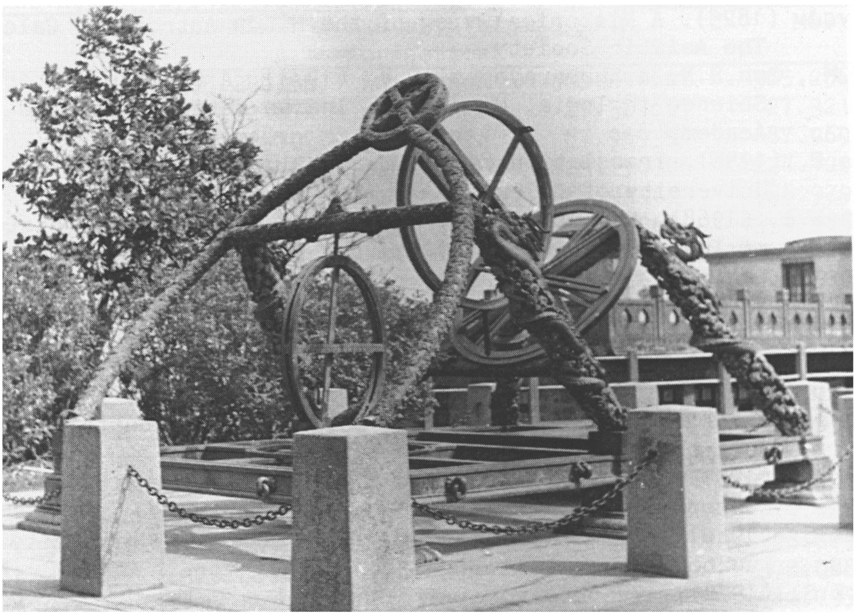

Abridged Armilla. At the beginning of the Yuan Dynasty, astronomer Guo Shou-jing simplified the complicated ancient instrument so as to separate the circles of the horizontal coordinate system from those of the equatorial system. It can avoid the obscuration of the observable sky region by the many rings of the old instrument. It was made in 1437, the second year of the Zheng-Tong Reign of the Ming Dynastry.