CHAPTER – I

HISTORICAL BACKGROUND OF ASTRONOMY

The antiquity of astronomical studies in the Indian subcontinent can be traced from the pre-vedic periods. Inscriptions of astronomical phenomena are deciphered from the two Mohenjadaro seals dating at least 2500 B.C.\(^1\) An attempt by Finnish philologists to read the Indus script using a computer method seems to indicate that the \textit{nakshatras} are of Harappan origin, as also are the later Dravidian names of the five planets related to their colours (e.g. Mars, the ‘red star’). Should this be substantiated, it would locate the origin of the \textit{nakshatras}, traditionally associated with the Hindus, within the earlier Indus Valley Culture.\(^2\)

The science of astronomy was known to the Sangam people and the twin epics mention astronomical details. In Puram, 221 the position of stars and planets is given for the fall of a meteor in the reign of the Chera dynasty of the elephant look. In Purananūru, ode, 229 Küdalūrkilar describes elaborately the point in the sky where he saw a shooting star.\(^3\)

---


In Agam, 313 the setting of the sun is described with reference to the moon being swallowed up by the serpent and so on.⁴

Vedic Aryans in fact deified the sun, stars and comets. Astronomy was then interwoven with astrology and since ancient times Indians have involved the planets (called *Grahas*) with the determination of human fortunes. The planets *Shani*, i.e. Saturn and *Mangal* i.e. Mars were considered inauspicious.⁵

Astronomy, Astrology and Mathematics formed the three main divisions of *Jyothisham*. The movement of the stars and planets were studied from very early period and their influence on the weather; the plant life and human life were also recognized and studied. This resulted in the development of Astronomy and Astrology.⁶ Calculation of the time was part of the sacred ritual with the Vedic Aryans. Religious sacrifices that they performed were of different types. While some of them were performed at a particular time of the day, the others were performed at full or new moon or when the days and nights were of equal length, and occasionally a sacrificial ritual lasted even for a year or more. Not only that, the sacrificial altar had to face a particular direction also, as for example,

---
⁵ www.sudhanshu.com/history.html
the east. So we see that the Aryans had to have a fairly broad based idea of the time and the direction, from very early times.\(^7\)

The Vedic literature produced during this period is voluminous, though only stray passages therein are wholly astronomical in content. This literature includes, primarily, the four Vedic Samhitas, viz., Rig Veda, Yajur Veda, Sāma Veda and Atharva Veda, in their several recensions. The extensive elucidatory literature thereon, called the Brāhmaṇas, and the supplementary texts thereto, called Āranyakas; the philosophic expositions called Upanisads; and the six Vedāngas. Two of these six Vedāngas, Viz., Jyothisha and Kalpa, the latter in its last section called Sulba, are of particular importance in the study of the growth of astronomy in India. The former, viz., *Vedānga – Jyothisha*, being short texts attached to the Rig-Veda, Yajur Veda and the Atharva Veda sets out certain definite aspects of Vedic astronomy, while the latter, viz., the Sulbasūtras, being menstruation manuals for the construction of different types of fire altars, such as Baudhayāna, Āpastamba, Kātyāyana, Mānava, Maitrāyaniya, Vārāha and Vādhūla, codify the practical side by vedic astronomy. The two epics of India, viz, the Mahābhārata and the Rāmāyana, which too, belong to the pre-scientific age of Indian astronomy, contain several useful references. So also the earlier purāṇa texts. The Jainas had fervour for mathematics and in

---

some of their canonical texts is to be found a section named Ganitānuyoga ‘system of calculation’. The Jaina texts also contain astronomical material. Last to come in this period are the five systems of astronomy viz., the Paitāmaha–Siddhānta, Vāsistha–Siddhānta, Saura–Siddhānta, Romaka – Siddhānta and Pauliśa–Siddhānta, whose original texts are not available now, but whose tenets have been set out by Varāhamihira in his Pānchā- Siddhāntikā (A.D. 505).

**Early texts:**

"Like the crests on the heads of peacocks, like the gems on the hoods of the cobras, jyothisha (Astronomy) is at the top of the vedānga sastras – the auxiliary branches of Vedic knowledge".

*Vedānga Jyothisha, 4*

The above verse shows the singular importance given to astronomy (and mathematics) over the other branches of knowledge in the vedic times. In the vedic literature, *Jyothisha* is one of the six auxiliaries (shadangas) of the vedic corpus of knowledge. The six Vedāngas are

i. Siksa (phonetics)

ii. Vyākarana (grammar)

iii. Chandas (metrics)

iv. Nirukta (etymology)
v. Jyothisha (astronomy) and
vi. Kalpa (rituals)

It is important to note that although in modern parlance the word Jyothisha is used to mean predictive astrology, in the earlier literature Jyothisha included all aspects of astronomy. Mathematics was regarded as a part of Jyothisha. Vedānga Jyothisha is the earliest Indian astronomical text available.  

In the early works direct references to the subject of astronomy are very few. In the Yajur Veda the *nakshatradarsa* (star-gazer or astrologer) is mentioned as one who would bring 'insight if offered up as a sacrifice; and in the same list of human victims the *ganaka* (calculator or astrologer) is said to bring 'power' to the sacrificer. The Chāndogya Upanishad gives lists of subjects known to Nārada and these lists include *nakshatra vidyā* (astronomy) and *rāsi* (quantity or number).

**The Rig Veda:**

In Rig Veda the sun is the source of light, out-strips all in speed, measures day and night, drives away the stars and night like thieves.

---

10 Ibid., XXX, 20, p. 455.
13 Ibid., I, 50, p.138.
14 Ibid., I, 50.
The sun’s chariot has seven\textsuperscript{15} horses generally but occasionally five, or six, or a thousand.\textsuperscript{16} Occasionally the sun was overspread with darkness by Svarbhānu, which was dissipated by Atri and by prayer.\textsuperscript{17}

The moon appears to order the seasons and is continually born again. The sun and moon ‘ascend alternate’, and move in close succession\textsuperscript{18} but the moon plays a subordinate part throughout, although Soma (afterwards a Moon–God) is, from a non-astronomical point of view, of supreme importance.

The year has twelve months and 360 days, and is divided into four quarters of 90 days each.\textsuperscript{19} There is no definite reference to a five year cycle,\textsuperscript{20} nor any explicit reference to an intercalary month.\textsuperscript{21} The account of the Ribhus reposing for twelve days\textsuperscript{22} has been supposed to imply a lunar year of 354 days with the 12 additional days making 366 in all.

There are doubts about the mentioning of some planets in Rig Veda. A great deal of ingenuity has been exercised in trying to discover references

\textsuperscript{15} Ibid., I, 50\textsuperscript{8}, p.139, I, 164\textsuperscript{2}, p. 397, VI, 44\textsuperscript{24}, p. 553 etc.

\textsuperscript{16} O.M.C. Narayanan Namboodiripad, \textit{Rig Veda Bhasha –Bhasham (Mal.)}, V, 62\textsuperscript{1}, Vol.4, Kottayam, 1982, p.244.

\textsuperscript{17} Ibid., V, 40\textsuperscript{4–8}, Vol.4, pp. 111-113, IV, 28\textsuperscript{3}, Vol.3, p.480.

\textsuperscript{18} Vallathol, \textit{Rig Veda Samhita} (Mal.), X, 85\textsuperscript{18}, Vol. IV, Trichur, 1958, p. 366.

\textsuperscript{19} O.M.C. Narayanan Namboodiripad, \textit{op. cit.}, Vol.2, I, 164\textsuperscript{11}, p.399, I, 164\textsuperscript{48}, p.408, I, 155\textsuperscript{6}, p.378.

\textsuperscript{20} Ibid., But see, III, Vol.2 55\textsuperscript{18}, p. 267.

\textsuperscript{21} V. Balakrishnan and R. Leela Devi, \textit{op. cit.}, I, 25\textsuperscript{8}, p. 272 has been supposed to imply an intercalary month

\textsuperscript{22} O.M.C. Narayanan Namboodiripad, \textit{op. cit.}, IV, 33\textsuperscript{7}, Vol.3, p. 512.
that imply the planets or a knowledge of them but without any assured success. Brihaspati was later on the name for Jupiter and it is possible that in the Rig Veda the planet is meant by Brihaspati\textsuperscript{23} but this is only conjecture. The cloud-born Vena\textsuperscript{24} has been equated with Venus but without general acceptance.

Of constellations there are few definitely mentioned: \textit{Aghās} and \textit{Arjunī}\textsuperscript{25} are usually identified with the adjacent asterisms \textit{Maghā} and \textit{Phalguni}; \textit{Tishya} may be a special star.\textsuperscript{26}

The Yajur-Veda:

The Yajur Veda (Taittirīya Samhitā) gives a list of twenty-seven asterisms or \textit{nakshatras}, commencing with Kṛttikā.\textsuperscript{27} It also states definitely that “the full moon in Phalguni is the beginning of the year”.\textsuperscript{28} Thus the Taittirīya Samhitā gives the two most important contributions to vedic astronomy. Nakshatra lists are also given in the Maitrayani and Kathaka Samhitās and in the Atharva Veda.

\textsuperscript{23} Ibid., IV, 50\textsuperscript{4}, p. 578.
\textsuperscript{24} Vallathol, \textit{op.cit.}, X, 123\textsuperscript{2}, p. 468.
\textsuperscript{25} O.M.C. Narayanan Namboodiripad, \textit{op.cit.}, X, 85\textsuperscript{13}, Vol.7, p. 366.
\textsuperscript{26} Vallathol, \textit{op. cit.}, V, 54\textsuperscript{13}, p.206, X, 64\textsuperscript{8}, p. 322.
\textsuperscript{27} Arthur Berriedale Keith, \textit{The Veda of the Black Yajus School entitled Taittirīya Samhita Part 2: Kandas IV-VII}, IV, 4\textsuperscript{10}, Delhi, 1914, p.349.
\textsuperscript{28} Ibid., VII, 4\textsuperscript{4}, p. 607.
The Atharva Veda:

The Atharva Veda refers explicitly to a thirteenth month of 30 days,29 which possibly implies a five year cycle of $5 \times 360 + 30 = 1830$ days, such as is exhibited in the *Vedanga Jyotishta* etc. The names of the year as given in several of the Samhitās are of no astronomical value.30 The Atharva Veda also mentions eclipses on several occasions31 and introduces Rahu,32 the demon of eclipses; Soma and Rudra remove the eclipse.33 The *nakshatra* list of the Atharva Veda consists of 28 asterisms and is apparently of an astrological character.34

Subsidiary texts:

The Brāhmanas add very little of astronomical value. A Brāhmaṇa or religious manual and a Sutra or collection of rules are attached to each Veda; and that the Brāhmaṇa is further divided into three rather vague orders of which the Vedanta or Upanishad is chiefly concerned with theosophical speculations.35 The Vedāngas are subsidiary works of later date dealing with the several branches of secular knowledge. There are definite references to a thirteenth month of thirty-five days or thirty-six

---

days. The Upanishads add nothing of special interest except, perhaps, a reference to the 'fixed' (dhruva) pole star. The nakshatras appear to occupy equal spaces of $13\frac{1}{3}$ degrees and the year appears to be divided at the beginning of Māgha\(^{36}\) or the end of Aslesha\(^{37}\). The terms ketu and graha are employed but not with any definite astronomical denotation.\(^{38}\)

**Vedāṅga Jyotiṣha:**

*Vedāṅga Jyotiṣha* is the earliest Indian astronomical text available. The *Vedāṅga Jyotiṣha* was mainly used to fix suitable times for performing different kinds of sacrifices. The text is found in two recensions—Rig Veda Jyotiṣha and Yajur Veda Jyotiṣha. Though the contents of both the recensions are the same, they differ in the number of verses. While the Rig Vedic versions contain only 36 verses, the Yajur Vedic version contains 44 verses. This difference in the number of verses is perhaps due to the addition of explanatory verses by the Adhvaryu priests by whom it was used.

In one of the verses, it says, “I shall write on the lore of time, as enunciated by sage Lagadha”.\(^{39}\) Therefore, the authorship of *Vedāṅga Jyotiṣha* is attributed to Lagadha. Hence Lagadha is sometimes called the father of Indian astronomy.\(^{40}\)

---

\(^{36}\) Magha is the tenth lunar asterism, sometimes regarded as the wife of the moon in Hindu mythology.

\(^{37}\) Aslesha is the seventh lunar asterism.


The *Vedānga Jyotihsha* belongs to the last part of the Vedic age. The text can be considered as a record of the fundamentals of astronomy necessary for the day-to-day life of the people of those times. The *Vedanga Jyotihsha* is the culmination of the knowledge developed and accumulated over thousands of years of the Vedic period up to 1400 B.C.

Even as early as the time of the mandalas of the Rig Veda, the Vedic people were conversant with the knowledge required for their religious activities, like the times (and periodicity) of the full and the new moons, the last disappearance of the moon and its first appearance, etc. This type of information was necessary for monthly rites like darsapurnamasa and seasonal rites like cāturnāśya.41

The Nakshatra System consisting of 27 nakshatras (or 28 including Abhijit)42 was evolved long ago and was used to indicate days. It is pointed out that Agrahāyana, an old name for the Mrigasira nakshatra, meaning “beginning of the year” suggests that the sun used to be in that asterism at the time of the vernal equinox. This corresponds to the period around 4000 B.C.

During the Yajur Veda period, it was known that the solar year has 365 days and a fraction more. In the Taittirīya Samhitā, it is mentioned that

---

41 S. Balachandra Rao, *op. cit.*, p. 3.
42 Abhijit is the twenty seventh lunar mansion.
the extra eleven days over the twelve lunar months, totaling 354 days, complete the six ātus by the performance of the ekadasa-rātra, i.e., eleven-night’s sacrifice. Again, the same Samhitā says that five days more were required over and above the sayana year of 360 days to complete the seasons, adding specifically that: “four days are too short and six days too long”.

The Vedic astronomers evolved a system of five year’s Yuga. The names of the five years of a Yuga are:

i. Samvatsara

ii. Parivatsara

iii. Idavatsara

iv. Anuvatsara, and

v. Idvatsara.

This period of a Yuga (of five years) was used to calculate time.

In the Yajur Veda, a year comprising twelve solar months and six ātus (seasons) was recognized. The grouping of the six ātus and the twelve months, in the Vedic nomenclature, is as follows:
<table>
<thead>
<tr>
<th>Seasons</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Vasanta ṛtu</td>
<td>Madhu and Mādhava</td>
</tr>
<tr>
<td>2 Grīśma ṛtu</td>
<td>Śukura and Śuci</td>
</tr>
<tr>
<td>3 Varṣa ṛtu</td>
<td>Nabhasa and Nabhasya</td>
</tr>
<tr>
<td>4 Śarad ṛtu</td>
<td>Isha and Urja</td>
</tr>
<tr>
<td>5 Hemanta ṛtu</td>
<td>Saha and Sahasya</td>
</tr>
<tr>
<td>6 Śisira ṛtu</td>
<td>Tapa and Tapasya</td>
</tr>
</tbody>
</table>

The sacrificial year commenced with Vasanta ṛtu. The Vedic astronomers had also noted that the shortest day was at the winter solstice when the seasonal year Śisira began with āttrayana, and rose to the maximum at the summer solstice.

In the *Vedāṅga Jyotishā* a *Yuga* of 5 solar years, consists of 67 lunar sidereal cylices, 1830 days, 1835 sidereal days, 62 synodic months, 1860 tithis, 135 solar nakṣatras, 1809 lunar nakṣatras and 1768 risings of the moon. It also mentions that there are 10 ayanas and visuvas and 30 ṛtus in a *Yuga*.

---

43 A celestial meridian is an imaginary line in the celestial sphere, fixed relative to the stars. The moon is observed to cross any particular meridian every 27.3 days. This is the sidereal period or sidereal month.

44 A synodic month is the interval between successive conjunctions of the moon and sun i.e from any new (or full) moon to the consecutive new (or full) moon. The synodic month is also known as lunar month.

45 One tithi is one lunar day. One tithi is the interval of time during which the moon gains 12 degree of longitude over the sun.

The practical way of measuring time is mentioned as the time taken by a specified quantity of water to flow through the opening of a specified clepsydra (water-clock), as one nādikā, i.e., \( \frac{1}{20} \)th part of day. The Vedāṅga Jyotishā also has a useful classification of those times like:

i. The solstices

ii. Increase and decrease of the durations of days and nights in the ayanas.

iii. The solstitial tithis

iv. The seasons

v. Omission of tithis

vi. Table of parvas

vii. Yoga's (which developed later as one of the five limbs of a full fledged pancanga)

viii. Finding the parva nakshatras and the parva tithis.

ix. The visuvas (equinoxes)

x. The solar and other types of years.

xi. The revolutions of the sun and the moon (as seen from the earth).

xii. The times of the sun's and the moon's transit through a nakshatra.

xiii. The adhikamasa (inter calary month)

xiv. The measures of the longest day and the shortest night etc.
The *Vedānga Jyothisha* mentions that the durations of the longest and the shortest days on the two solstices are thirty six and twenty four *ghaṭikā (nādikās)* which corresponds to 14 hours, 24 minutes and 9 hours, 36 minutes respectively. This means the *dinardha*, i.e. the length of half day, comes to be 7 h 12 m and 4 h 48 m respectively, which differs from 6 h by 1 h 12 m. This is called the ascensional difference. It is calculated that around 1400 B.C, the sun’s maximum declination used to be about 23°53’. However, our ancient Indian astronomers took it as 24°. Now, the latitude of a place can be found using the formula:

\[ \sin \text{(ascensional difference)} = \tan \phi \tan \delta \]

where \( \delta \) is the declination of the sun. The correction due to the ascensional difference in this case is 1 h 12 m, i.e., in angular measure, 1 h 12 m \( \times 15° = 18° \). By using the above formula, we get the latitude of the place as \( \phi = 35° \) approximately. Therefore, the place of composition of the *Vedānga Jyothisha* appears to be in some region around the northern latitude of 35 degrees.47

Rāmāyana and Mahābhārata:

The Mahābhārata, Rāmāyana and the Purānas occupy a peculiar position in the history of Hindu astronomy. They embody certain ancient astronomical traditions. They contain a good deal that does not obviously

---

appertain to the earlier period. On other than astronomical grounds the later limit of portions of the *Mahābhārata* has been fixed at about A.D. 400 and the texts of the Purāṇas generally contain unambiguous evidence that they are at least as late as that date. Citations from the epics and the pseudo historic Purāṇas must therefore be employed with circumspection.\(^{48}\) The *Mahābhārata*, the longest epic poem contains interesting material of a quasi-astronomical nature.\(^{49}\) The five year cycle is mentioned and it is stated that there would be an excess of two months in five years, and of five months six days in thirteen years.\(^{50}\) The Kṛita Age is also mentioned without specifying the length of the period, and it is said that it will come again when the sun, moon, the nakṣatra Tishya (=Pushya) and Jupiter meet in one sign.\(^{51}\) The nakṣatras are generally 27 in number\(^{52}\) but 28 seem occasionally to be implied.\(^{53}\) The month begins with the bright fortnight (new moon to full moon) and a half month contains 14, 15 or 16 days. An eclipse occurring on the 13th day is mentioned.\(^{54}\) The planets are mentioned by name in the following order: “Venus, Jupiter, Mercury, Mars, Saturn, Rahu and the other planets”.\(^{55}\) The stars though “so small in consequence of their distance, are large”.\(^{56}\)


\(^{49}\) Ibid., p. 14.


\(^{51}\) Ibid., III, 190\(^{90}\), Vol. 1, p. 656. Pushya is supposed, more or less, to coincide with cancer. See also the Ramayana, I, 60.

\(^{52}\) Ibid., I, 66\(^{16}\) Vol. 1, p. 98.

\(^{53}\) Ibid., V, 110\(^{15}\), Vol.2, p. 1031.

\(^{54}\) Ibid., VI, 3\(^{32}\), Vol.2, p. 1132.

\(^{55}\) Ibid., II, 11\(^{37}\) Vol. 1, p. 305.

\(^{56}\) Ibid., III, 42\(^{24}\), Vol. 1, p. 446.
The Rāmāyana:

The Rāmāyana mentions a number of nakshatras and generally with reference to the position of the moon and in one case Pushya appears to be equated with Mīna (Pisces). Of particular constellations the Great Bear and Trisanku occur. The planets Mars, Mercury, Jupiter and Venus are definitely mentioned. One whole canto is devoted to the glory of the sun. Rahu, as the enemy and devourer of the moon, is mentioned on several occasions, but Ketu does not appear to occur. Meru is stated to be the best of mountains and is generally coupled with some other mountain range, e.g., Vindhya, Himavān.

The Purānas:

The chief characteristic of the Purānas is perhaps connected with cosmological notions. The following is condensed from the Vishnu Purāna. The seven great islands are surrounded by seven great seas. Jambū-dvīpa is the centre of all these; and in the centre of this is the golden mountain Meru. The height of Meru is 84,000 yojanas and its depth below 16,000. Its diameter at the summit is 32,000 and at its base 16,000; so that this

58 Ibid., Canto XIX, Book 1, p. 32.
59 Ibid., Canto XIX, Book 1, p. 31.
60 Ibid., Canto CVI, Book 6, p. 489.
61 Ibid., Canto IV, Book 2, p. 93.
62 Ibid., Canto I, Book 1, p. 4.
mountain is like the seed cup of the lotus of the earth.... The orbit of the sun is 100,000 yojanas from the earth and that of the moon an equal distance from the sun. At an equal distance above the moon is the sphere of the *nakshatras*. Mercury is 200,000 yojanas beyond, Venus 200,000 further still, Mars 200,000, Jupiter 200,000 and Saturn 250,000 yojanas beyond Jupiter. The sphere of the seven Rishis is 100,000 yojanas beyond and at the same distance above is Dhruva, the pivot or axis of the whole planetary circle.\(^63\) One of the most extraordinary astronomical theories that occur in Hindu literature is connected with the seven Rishis, which are generally identified with the Great Bear. The principal authorities are the Pauranic texts and Varahamihira.\(^64\) Beyond Dhruva are the four heavens.... on Dhruva rest the seven great planets, and on them depend the clouds. As Dhruva revolves it causes the moon, sun and stars to turn round also, and the *nakshatras* follow in its circular path: for all the heavenly bodies are, in fact, bound to the polar star by aerial cords....

This order was not strictly followed by the later astronomers who placed the sun in its correct relative position and the *nakshatras* or stars beyond the furthest planet, and omit the seven Rishis and Dhruva. Besides the five planets, Rahu and Ketu are mentioned and each of the seven has a chariot drawn by eight horses.\(^65\)


\(^{64}\) G. R. Kay, *op. cit.*, p. 16.

It is implied that the winter solstice takes place at the beginning of the month Tapas (Māgha), and an equinoxes, apparently, supposed to take place in Kṛttikā or Visākhā.\textsuperscript{66} There is also a reference to the recurrence of the Kṛtā age similar to that given in the epic.

\textbf{The Jatakas:}

Buddhist texts are often severe in their condemnation of star-gazing, astrology and such practices as the foretelling of eclipses; but the Jatakas contain fairly numerous references to astronomical matters.\textsuperscript{67} In number 20 the Kappa or era, with its four era miracles is mentioned, the first of these miracles being ‘the sign of the hare in the moon, which will last the whole era.’\textsuperscript{68} In number 48 a charm is to be repeated at a certain conjunction of the planets, and the magician is made to say “It will be a year before the requisite conjunction of the planets takes place again.”\textsuperscript{69} Similar references to conjunctions of the planets are made in numbers 474,481 and 522. In number 481 the goblin on releasing the prince says: “Go forth from my hand, even as the moon from the jaws of Rāhu;” and such references to the demon of eclipses recur pretty often.\textsuperscript{70}

\textsuperscript{66} I\textsuperscript{bid.}, VIII, 17, 18, p. 185.
\textsuperscript{68} E. B. Cowell (ed.), \textit{The Jatakas}, Delhi, 1895, Vol. 1, p. 56.
\textsuperscript{69} I\textsuperscript{bid.}, p. 121.
\textsuperscript{70} G. R. Kay, \textit{op.cit.}, p. 14.
Jaina Astronomy: The Śūryaprajñapti

The principal source of information about the Jaina astronomical text is the Śūryaprajñapti. The Śūryaprajñapti is, from the astronomical point of view, of much the same type as the Vedāṅga Jyotihsha but, possibly, it is of a later period. Popularly the most marked feature of the system set forth in the Śūryaprajñapti is the somewhat strange cosmography that appears to have been peculiar to Jaina teaching.

The cycle is divided into five lunar years of which the first, second and fourth consist of 12, and the 3rd and 5th of 13 synodic months. The synodic month is also divided into two lunar ayanas and six lunar seasons.

The cycle commences at the summer solstice when the moon is full at the beginning of Abhijit and thus differs from the Vedāṅga Jyotihsha. If Abhijit is to be identified with α lyrae, as it invariably has been, then the date of observation must have been about A. D. 850, when the winter solstice took place at the same longitude as α Lyrae.\(^7\)

The sun revolves round Mount Meru always at the same height from the plane of the earth, namely 800 yojanas, but at varying distances from Mount Meru. The radius on the longest day is 49,820 yojanas and on the shortest day it is 50,330 yojanas. The longest day is, as in the Vedāṅga

Jyothisha, 18 muhūrtas ( = 14.4 hours), and the shortest 12 muhūrtas ( = 9.6 hours) and the daily change is 1.57 minutes, and the corresponding latitude would be about 36 degrees.

To overcome the difficulty of explaining the rising and setting of the sun it is assumed that the body becomes visible only when he is within a distance equal to half the extent of his day’s journey. The moon is also supposed to move in concentric circles round Meru at a distance of 880 yojanas from the plane of the earth, that is 80 yojanas further away than the sun. It enters into conjunction with the sun 62 times and completes 67 sidereal revolutions in the five years. It is mentioned in the Sūryaprajñapti that the planets travel faster than the sun and the stars, faster than the nakshatras.72

Siddhānta:

The astronomical computations described in the Vedāṅga Jyothiṣha were in practical use for a very long time. Around the beginning of the Christian era, say a century on either side of it, a new type of Indian astronomical literature emerged. The texts representing this development are called Siddhanta. The word “Siddhānta” has the connotation of an

72 Ibid., p. 21.
established theory. These Siddhānta texts contain much more material and deal with more topics than the *Vedānga Jyothiśha*.

Along with the Nakshatra System, the twelve signs of the Zodiac, viz., Meṣa, Vṛṣabha, etc. were introduced. A more precise value for the length of the solar year was adopted. Computations of the motions of the planets, the solar and lunar eclipses, ideas of parallax, determination of mean and true positions of planets and a few more topics formed the common contents of the Siddhāntic texts.

A very significant aspect of that period, and of the history of Indian astronomy, was the remarkable development of newer mathematical methods which greatly promoted mathematical astronomy. Needless to say, the unique advantage of the famous Hindu decimal numbers made even computations with huge numbers very simple, and even enjoyable, to the ancient Indian astronomers.

According to the Indian tradition, there were principally 18 Siddhantas: Sūrya, Paitāmaha, Vyāsa, Vāsiṣṭha, Atri, Parāśara, Kāśyapa, Nārada, Gārgya, Marīchi, Manu, Ārigūra, Lomasa (or Romaka), Pauliśa, Cyavana, Yavana, Bhrigu and Saunaka. However, among these, only five Siddhāntas were extant during the time of Varāhamihira (505 A.D.) viz. Saura (or Sūrya), Paitāmaha (or Brahma), Vāsiṣṭha, Romaka and Pauliśa.
These five Siddhāntas were ably compiled by Varāhamihira and preserved for posterity as his *Pancha-Siddhāntikā*.

Paitāmaha Siddhānta (2nd century A.D.) retained the Vedāṅga astronomical system. Āryabhatta I wrote the Sūrya Siddhānta, had some Greek influence dealt with the epicyclic revolution of the earth around the sun, the nature of eclipses, reckoning of time, longitudes with the prime meridian passing through Ujjayini.

**Hindu Astronomical Instruments:**

The only instruments of practical utility for astronomical purposes described in ancient Hindu works are the sun-dial and clepsydra. An armillary sphere is also described as an instrument for purposes of demonstration. The only Hindu instrument of any antiquity actually found is the clepsydra, consisting of a metal bowl floating in a vessel of water.

The following is a summary of those parts of the early Hindu texts that deal with astronomical instruments.

(i) The clepsydra or water clock is referred to in the *Vedāṅga Jyotihisha*, where the amount of water that measures a *nādikā* (=24 minutes) is given. The more ancient form of water clock, appears to have been

---

74 *Civil Services Chronicle*, January 2007, p. 125.
simply a vessel with a small orifice at the bottom, through which the water flowed out in a nādikā, but later on there came into use the form described in the Sūrya Siddhānta (xiii, 23): “A copper vessel, with a hole in the bottom, set in a vessel of pure water, sinks sixty times in a day and night, and is an accurate hemispherical instrument”. The Pancha-Siddhantika description (XIV, 32) is similar, but adds “or else a nādikā may be measured by the time in which sixty slokas, each consisting of sixty long syllables, can be read out”. A later description of the clepsydra is as follows: “A copper vessel, weighing 10 palas, six angulas in height and twice as much in breadth at the mouth, this vessel of the capacity of 60 palas of water, and hemispherical in form, is called a ghati. The aforesaid copper vessel, bored with a needle made of 3 ½ mashes of gold and 4 angulas long, gets filled in one nādikā”.

In practice, no doubt, the dimensions of the bowl and the orifice were determined by experiment. Bhāskara (XI, 8) indeed says: “See how often it is filled and falls to the bottom of the pail of water in which it is placed. Divide 60 ghatis of day and night by the quotient and it will give the measure of the clepsydra”.

(ii) The Gnomon - The sun-dial described in the early treaties is of the simplest kind, consisting of a vertical rod, or gnomon, divided into
12 divisions. The descriptions are of a theoretical nature, and do not apply so much to the construction of instruments as to theoretical calculations.\textsuperscript{75}

Thus, whatever may be the real facts regarding the order in which each nation might have acquired its astronomical system, there is enough material in these similarities to establish the fact that the pre-historic astronomy of the world was founded by the Aryans of central Asia.

Of the great antiquity of Indian Astronomy, the first evidence was afforded to western investigators by the publication of certain astronomical tables in the \textit{Memoirs of the Academy of Sciences} in 1687 by M. Le Loubore, which were taken from India. These were examined by Cassini.

Two other tables were also secured by the French missionaries, when they were in India,

\begin{itemize}
  \item[i] \textit{The tables of Krishnapuram and Narsapur} and
  \item[ii] \textit{The tables of Tiruvalore}, published by Le Gentil in 1772. He had come to India to observe the transit of Venus in 1769. He learnt from the pandits of Tiruvalore the method used by them in the calculation
\end{itemize}

\textsuperscript{75} G. R. Kay, \textit{op. cit.}, p. 67.
of eclipses etc. Another French astronomer who made a study of these tables is M. Bailly; also Professor Playfair, who studied Bailly’s work, verified all the calculations and tables prepared by the latter; and it has been concluded that.

a. The observations, on which the astronomy of India is based, were made more than three thousand years Before Christ and, in particular, the places of the sun and moon were determined accurately by actual observation;

b. The construction of these tables implied a great knowledge of geometry, of arithmetic and even of the theoretical parts of spherical astronomy. The real foundation of a proper knowledge of the history of Hindu astronomy was laid by Weber (1860-1868), Whitney (1858) and Thibaut (1877-1889). Weber gave us the *Vedānga Jyotishā*, etc., Whitney a translation, together with a critical commentary, of the Sūrya Siddhānta, and Thibaut the *Pancha-Siddhantika* of Varāhamihira; and with these should be mentioned Sachau’s translation (1888) of *Albīrūni’s India*. These contributions settled definitely the question of the connection between the later Hindu astronomy and that of the Greeks, and the

---

orientalists was consequently directed to the earlier periods that had been designated Vedic and post Vedic. It is important to remember that ancient Indian knowledge on all these aspects are not merely religious or spiritual, but are purely scientific.

Scientific Astronomy

Scientific astronomy might be said to have commenced when the fundamentals of the science had been established and strict rules and procedures of computation had been formalized. The system could then grow on a rational basis. In the history of astronomy, the scientific period could be said to have started towards A.D. 500, with Āryabhatta (born A.D. 476), from when on there has been a long line of recorded astronomical tradition reaching down to the seventeenth century in general and right up to the nineteenth century in remote corners in India like Kerala. This period of nearly one and half millennia produced several lines of astronomers who maintained the tradition and also made substantial original contributions, some of which were re-discovered, much later, in modern astronomy.

77 G. R. Kay, op. cit., p. 5.
78 Bina Chatterjee, Indian Astronomical knowledge 1300 years ago-Sīshyadhiruddha tantra of Lalla Charya, Thiruvananthapuram, p. 21.
The scientific astronomy may be conveniently divided into two sub-periods, of which the earlier one only has historical importance. This may be considered to coincide pretty closely with the period of the Gupta dynasty (A.D. 320-650) and it embraces the most celebrated of the Hindu astronomers - Āryabhatta, Varāhamihira, Brahmagupta and their contemporaries. In the history of civilization generally this period is of exceptional interest. In India the period was productive of many important works in mathematics, astronomy, astrology, medicine, poetry and drama.

The second sub-period which extends from about A.D. 700 to the present day, is of sub-ordinate interest altogether in India. Bhāskara II is the only conspicuous figure and his importance has been some what exaggerated. His Siddhānta Siromani is, however, one of the best known of the Hindu works.\(^8^0\)

Scientific astronomy can be said to have been enunciated in India by Āryabhatta I (A.D. 476), his pupil Latadeva (A.D. 505), Varāhamihira, Brahmagupta, Bhaskara I (a contemporary of Brahmagupta and a disciple of Āryabhatta I), Lalla, author of Sisyva Dhiwriddhita, Sumati (A.D. 800), author of Sumati Tantra and Sumati Karana, Manjula (A.D. 930), Āryabhatta 11 (A.D. 950), Śripati (A.D. 1039), author of the Siddhānta Sekhara and Ganita Tilaka and Bhāskara II (A.D. 1150) who wrote the

\(^8^0\) G. R. Kay, op. cit., pp. 8-9.
important treatise *Siddhānta Siromani*, were the Hindu astronomers and most of them also made significant contributions to mathematics.\(^{81}\) Calculations based on the scientific astronomy are used even to this day with a fair amount of accuracy and ephemerides are published in various parts of India, based upon this system of reckoning.\(^ {82}\)

The achievements of some of the great astronomers such as Āryabhatta I, Varāhamihira, Brahmagupta, Bhāskara I and Bhāskara II are monumental.\(^ {83}\)

Āryabhatta

The most famous Indian mathematician cum astronomer of yore is undoubtedly the great Āryabhatta (b. A.D. 476) whose A.D. 479 text *Āryabhattiya* (meaning Āryabhatta’s work) was the first astronomical work that was attributed to a single author and accurately dated. *Āryabhattiya* exercised profound influence on later developments. For more than a thousand years, it was commented upon, followed, adapted, or criticized, but never ignored.\(^ {84}\)

Many things about him—his place of birth, his date of birth and even his real name are still subjects of controversy. The situation becomes all the

---


\(^ {82}\) O. R. Walkey and H. Subramania Aiyar, *op. cit.*, p. 5.


\(^ {84}\) A. Rahman (ed.), *History of Indian Science, Technology and Culture A. D. 1000-1800*, New Delhi, p. 178.
more confusing because of the indications that more than one mathematician bearing the name Āryabhatta flourished in India at various periods. That there were at least two Āryabhattas is beyond doubt:

(i) Āryabhatta of Kusumapuram who wrote the Āryabhātiyam in 499 A.D. and

(ii) Āryabhatta who wrote the astronomical treatise called the Maha Ārya Siddhānta (950 A.D.).

To distinguish between the two, the author of the Āryabhātiyam is called Āryabhatta I, and the author of the Maha Siddhānta is called Āryabhatta II. With regard to his place of birth, it is argued that Kusumapuram was not Āryabhatta’s place of birth; which has been born out by the statement: “Aśmakajanapādajāta Āryabhattachārya” (Āryabhatta who was born in Aśmakajanapādam) contained in Nilakantha’s commentary on Āryabhātiyam. It is therefore possible that Āryabhatta was born in Aśmakajanapādam and later he migrated to Kusumapuram (modern Patna).

The Persian scholar Al-Birūnī (A.D. 973-1043) has, on occasions more than once, called him Āryabhatta of Kusumapuram. Bhāskara I (A.D.

---

87 S. Parameswaran, ‘Āryabhatta’, loc.cit., p. 69.
the earliest commentator of the Āryabhatiya, identifies Kusumapura with Pātaliputra in ancient Magadha, and the knowledge honoured at Kusumapura with the teachings of the ‘Svayambhuva or Brahma Siddhānta’.88

Magadha in ancient times was a great centre of learning. The famous University of Nālandā was situated in that state in the modern district of Patna. There was a special provision for the study of astronomy in this university; an astronomical observatory was a special feature of this university. Āryabhatta I has been designated as Kulapa (=Kulapati or Head of a University). It is quite likely that he was a Kulapati of the University of Nālandā which was in a flourishing state in the fifth and sixth centuries A.D. when Āryabhatta I lived.89 It seems that Āryabhatta was an Āṣmaka who lived at Pātaliputra (Modern Patna) in Magadha (Modern Bihar) and wrote his Āryabhattiya there.90

There are different opinions from various scholars regarding to his place of birth and it is a controversial subject. Some scholars prove him to be of Keralese origin but some others disapprove it.

89 Ibid., p. xix.
The facts supporting it are:

(1) The Āryabhattan School is specially associated with Kerala country. Practically all the astronomers of this school whose place of origin can be definitely determined belong to this part of India and also as all the astronomical works produced in Kerala, whether commentatorial or original treatises, follow the Āryabhattan school; also manuscripts of the works of this school are found mostly only in this part of the country. Probably Āryabhatta himself was a native of Kerala. He is called AŚmaka which is derived by commentators as belonging to the AŚmaka country. And in some quarters it is identified with the southern part of Kerala state.91 The region of AŚmaka as the place where he hailed has been taken as a sanskr̥tisation of the Malayalam place name Kotunna[l]ur in central Kerala.92 As for his connection with Kusumapuram (Pātalīputra) it is not as a native of that city, but as one who has adopted the Siddhānta venerated and followed by the people of Kusumapuram.93

(2) Āryabhatta has dated the year of composition of Āryabhāttiyam in the Kali era.94

---

94 K. V. Sarma, A History of the Kerala School of Hindu astronomy, op. cit., p. 72.
Dṛkkarana, an astronomical manual composed in Malayalam verse in A.D.1607-08, written by Jyeṣṭhadeva, author of the astronomical treatise Yuktibhāṣa throws some interesting light in this direction.

\[ \text{tadā hy Āryabhato nāma ganakas tv abhavat bhuvi} / \]

‘Jnānatunge’ ti Kalyabde jātaney avanitale //

‘Then, in the Kali year jnānatunga (3600 = A.D. 499) and astronomer by name Āryabhatta was born in this world.

giritungeti Kalyabde gani tam nirmitam param /

sāstram Āryabhatiyākhyam tasmin paryayam uktavān //

‘In the Kali year girirungeta (3623 = A.D. 522) was his work Āryabhattiya composed and therein he stated the revolutions of the planets.\[95\]

In the whole of India, it was only in Kerala and to some extent in the bordering areas of the Tamil country where Kali era and only Kali era was in common use; elsewhere in India the Vikram era and Saka era (founded in B.C. 58 and A.D. 78 respectively) were in vogue. Kollam era of Kerala, which is also in use now, was founded only in A.D. 825. Prior to that

\[95\] Ibid., p. 9.
astrologers, astronomers, mathematicians, scholars and writers of Kerala were using Kali era.96

The facts disapproving it are:

(1) The beginnings of astronomical and mathematical studies in Kerala are shrouded in obscurity. K. Kunjunni Raja mentions in his book “Astronomy and Mathematics in Kerala” that some enthusiastic scholars have claimed for Kerala the great Āryabhatta and Bhāskara I on the grounds that practically all the important astronomical and mathematical works produced in Kerala follow the Āryabhattan School, and that works of these ancient authorities have been very popular in that part of India as indicated by the existence of a large number of manuscripts and commentaries there. This claim does not seem to be tenable, for the Āryabhattiya does not contain any reference to Kerala, on the other hand it refers to Kusumapuram (Pātalīputra), though it is not definitely stated that the author belonged to that city. In the case of Bhāskara I it is true that he has been more popular in the South than in the North, but in his works he refers to places like Valabhi, Sthānvīśvara and Ujjayini, but not to any place in Kerala. Even popular traditions in Kerala do not claim these two scholars as belonging to that state. According to these

96 K. N. Menon, Āryabhatta, New Delhi, 1977, p. 57.
traditions the legendary astrologer-astronomer Vararuci is associated with the introduction of this science to Kerala.\textsuperscript{97}

(2) Bhāskaracharya calls him as ‘Asmakiya’ but it is not clear about where the Aṣmaka is! And this identification became critical through years.

(3) Even after sixty years from independence, there is no scientific evidence about Āryabhatta his place of birth, his date of birth and even his real name are still subjects of controversy.\textsuperscript{98}

Whether Āryabhatta was a native by birth of Kerala or not, may remain a subject of controversy but the hold that Āryabhāttiyam had on the later mathematicians cum astronomers of Kerala was without an equal; Āryabhāttiyam seems to be the one fountain head from which mathematicians cum astronomers of Kerala not only drank deep but also drew their inspiration for many centuries to come. Hence an analysis of the contents of Āryabhāttiyam is not only justifiable but has turned out to be a must as a prerequisite for the further study of Keralalese School of mathematics and astronomy.\textsuperscript{99}

\textsuperscript{97} K. Kunjunni Raja, \textit{Astronomy and Mathematics in Kerala}, Adyar, 1963, pp. 119-120.

\textsuperscript{98} Mathrubhumi Illustrated Weekly, September 23-29, 2007, pp. 9-10.

\textsuperscript{99} S. Parameswaran, ‘Āryabhatta’, \textit{loc.cit.}, p. 73.
Aryabhata and Scientific Indian Astronomy

Scientific astronomy can be said to have been enunciated in India by Aryabhata I, through his two works, the *Aryabhatta-Siddhānta* which is available only in the form of citations by later authors, and as summarized in the *Khandakhadyaka* of Brahmagupta, and the *Āryabhattiyya*, a full fledged work composed in A.D. 499. Aryabhata was an observer par excellence and, as a result of his investigations, he revised the then current astronomical parameters, introduced new techniques in calculation and established Hindu astronomy on a scientific basis.

Āryabhattiyya

The Āryabhattiyya, couched in 121 aphoristic verses is the earliest extant Indian treatise on scientific planetary astronomy. Its first section, called Gitikā -pāda, sets out in 13 verses the basic definitions, the main astronomical parameters, the zero point for the commencement of calculations, the positions of the apogees and the ascending nodes of the planets at the time of the author, the diameters of the earth and the planets, the obliquity of the ecliptic and the inclinations of the planetary orbits to the ecliptic and a table of sine differences. The second section, Ganitā-pāda, in 33 verses, is concerned with enunciations involving arithmetic, geometry and trigonometry. The third section, Kālakriya-pāda, in 25 verses, gives the
units of time, explains the motion of the planets by means of epicycles and
enunciates the methods for the determination of the mean and true positions
of the planets at any given time. The fourth section, Gola-pāda, in 50
verses, deals with the motion of the sun, moon and the planets on the
celestial sphere and the computation and graphical representation of the
solar and lunar eclipses.

Āryabhatta’s Contribution

Āryabhatta’s contribution to algebra, trigonometry and astronomy
are highly significant. Among them a special mention might be made of the
theory of indeterminate analysis of the first degree, the value of π correct to
four decimal places, the computation of the sine table, the use of the radian
measure of 3438 minutes of arc, advanced astronomical parameters, the
theory of planetary motion and the correct interpretation and computation
of the eclipses.\(^{100}\) Āryabhatta I contained a chapter on algebra in the
Āryabhattiya, which was used by Al-Birūnī.\(^{101}\)

Earth’s Rotation

Āryabhatta made significant contributions to the field of astronomy.
He also propounded the heliocentric theory of gravitation, thus predating

\(^{100}\) K. V. Sarma, A History of the Kerala School of Hindu astronomy, op. cit., p. 4.
\(^{101}\) Civil Services Chronicle, p. 125.
Copernicus by almost one thousand years. \(^{102}\) Āryabhatta promulgated the theory of the rotation of the earth. Against the current view that the earth was stationary at the centre of the universe and that all heavenly bodies revolved around it, Āryabhatta held that the earth rotated round its axis once in a sidereal day \(^{103}\) and through an angle of one minute of arc in one prana (equal to \(\frac{1}{6}\) of a vinadi, or 4 sidereal seconds)\(^{104}\) while the stars were fixed in space. \(^{105}\) The time for one sidereal rotation of the earth at the above rate would work out to 23\(^{h}\) 56\(^{m}\) 4\(^{s}\). 1, while the corresponding modern value is 23\(^{h}\) 56\(^{m}\) 4\(^{s}\). 091. The accuracy of Āryabhatta’s enunciation is remarkable.

**Opposition to Āryabhatta**

It is a highly interesting and, perhaps, instructive anecdote in the annals of Indian astronomy that the above theory of Āryabhatta is known to us from the writings of contemporary and later critics of Āryabhatta like Varāhamihira (A.D. 505), Brahmagupta (A.D. 628), Lalla (8\(^{th}\) cent.), Śripati (A.D. 1039) and Bhāskara II (b. 1114), who severely criticized Āryabhatta’s theory of the rotation of the earth. \(^{106}\)

---

\(^{102}\) www.sudhanshu.com/history.htm.

\(^{103}\) Kripa Shankar Shukla, *Āryabhattiya of Āryabhatta*, New Delhi, 1976, Kalakriya, Verse. 5, p. 91.


Decline and Resurgence of the System

Severe criticism, both veiled and open, against the system of Āryabhatta, coming as it did from acknowledged authorities, like Brahmagupta, Varāhamihira and Śripati, should have be devilled not only the laymen but also the professionals, and the study of Āryabhattan System gradually declined in North India. And, with the wide popularity gained by the great works of Bhāskara II (b. 1114) who followed in the wake of Brahmagupta and Śripati, the Āryabhattan System was practically effaced from North India.107

The Āryabhattan System, however, emerged with increased vigour south of the Vindhyas. The superiority of the astronomical parameters and the novel innovations of Āryabhatta had given rise to a ‘School of Āryabhattan Astronomy’, the followers of which called themselves Asmakiya-s (advocates of the school of the Aśmaka author, viz., Āryabhatta) or Bhatasisyas (students of Āryabhatta). Scholars of South India, comprising of Karnataka, Andhra, Tamilnadu and Kerala, avidly took to the study of the Āryabhattiya and produced several commentaries and a mass of literature based on the system of Āryabhatta.108

107 Ibid., p. 7.
Kerala adopted the basic tenets and practices of Āryabhattan astronomy. Practically every astronomical text produced in the land bases itself on the teachings of Āryabhatta. The efforts of Kerala mathematicians have been directed also towards the revision, correction and supplementation of Āryabhattan astronomy with a view to arriving at more accurate results.¹⁰⁹

Varāhamihira

Varāhamihira is a contemporary astronomer of Āryabhatta I.¹¹⁰ The ancient world is known through via the Siddhāntas or the astronomical treatises which in themselves exhibit a transition from the Paitāmaha Siddhānta, which retains the Vedāṅga astronomy, to the Sūrya Siddhānta of A.D. 400, which largely establishes the form of native astronomy for the duration of the Middle Ages. Varāhamihira A.D. 505 summarised in his Pancha-Siddhāntika the five Siddhāntas entitled Paitāmaha, Vāsishtha, Pauliṣa, Romaka and Sūrya.¹¹¹

Greek astronomical ideas were transmitted to India during the first four centuries of the Christian era. This period coincides with that of the growth of the Siddhānta literature, and the Romaka Siddhānta especially

---

¹⁰⁹ K. V. Sarma, A History of the Kerala School of Hindu astronomy, op. cit., p. 8.
shows signs of Greek influence, an influence which is notably present in the
terminology of astrological writings such as the Brihajjataka and
Laghujātaka of Varāhamihira. The Brihajjataka of Varāhamihira which
is popularly known as Hora is an authoritative work on Astrology. It
was also the period of close commercial intercourse between imperial Rome and
the coasts of Kerala and Tamilnadu, embracing both the Augustan age and
the Sangam age.

The Sūrya Siddhānta, in addition to the use of terminology and units
of Greek origin, employs epicyclic models in its planetary theory which
proves that the planet moves on an epicycle of radius $r$ which is carried on a
circle of radius $R$ and eccentricity $e$, the ‘deferent’ around the observer.
Thus we are dealing with two variables, the ‘mean distance’ $\alpha$ of the centre
of the epicycle from the apogee of the deferent, and the ‘anomaly’ $r$ which
determines the position of the planet on the epicycle. The problem now
arises to tabulate this rather complicated function of $\alpha$ and $\gamma$. Into this
Greek geometrical system the Hindus injected the important concept of the
sine of an angle, thus initiating a second tradition which may be called as
‘trigonometrical’. Both the Pauliśa and Sūrya Siddhāntas contain a table of
sines.

---

Varahamihira mentions that among the five systems of Pancha Siddhántika - Paitämaha, Vāsishtha, Pauliśa, Romaka, and Sūrya. The Sūrya Siddhānta is the best. Even to this day the most popular astronomical text is Sūrya Siddhānta, though in its revised form. It is believed that the modern version of Sūrya Siddhānta was composed around 1000 A.D.\textsuperscript{115}

The chapters of the Sūrya Siddhānta deal with the mean motions of the planets, the true positions of the planets, direction, place, and time, the nature of eclipses, planetary conjunctions, asterisms, heliacal risings and settings, the rising and setting of the moon, certain malignant aspects of the sun and moon treated in part astrologically, cosmogony, geography, and the dimensions of the creation, measuring instruments such as armillary sphere, clepsydra, and gnomon, and different ways of reckoning time.

Highly regarded and widely disseminated, the Sūrya Siddhānta had a profound influence on the course of medieval Hindu astronomy. According to Sumati (A.D. 800), whose work was known both in Nepal and in Kerala, and who wrote his \textit{Sumati tantra} and \textit{Sumati karana} on the basis of the earlier version of the Sūrya Siddhānta, it provided the essential elements used by Nepalese astronomers in their construction of the Hindu calendar. Evolving during the period between A.D. 628 and 966, the later version gained greatly in popularity, especially in the twelfth century, when

\textsuperscript{115} S. Balachandra Rao, \textit{op. cit.}, p. 10.
Bhāskara II quoted from it and Mallikarjuna Suri wrote commentaries on it, first in Telugu then in Sanskrit. K. S. Shukla lists a minimum twenty eight commentaries on it.

**Brahmagupta**

Brahmagupta was born in 598 A.D. whilst Āryabhatta I excelled as an observer and in the classification of astronomical data; Brahmagupta was stronger as a mathematician. Brahmagupta wrote the *Brahmagupta Siddhānta* (mostly astronomy), *Dhyana-Grahopadesadhyaya* and his most important mathematics books *Khandakitadyaka* and *Uttarakhandakhadyaka*. *Patiganita* = science of arithmetics and geometry. *Bijaganita* = algebra.¹¹⁶

The astronomical writings of Brahmagupta were known in Western India at the time of the Muslim invasion of Sind (A.D. 712) and also to Abū Raihān-al-Bīrūnī on his Indian journey some three centuries later, and there is little doubt that they were one of the media through which Hindu astronomy and mathematics passed to the Arabs during the ‘Abbāsid Caliphate’ through whom it spread to many countries of Europe. Al-Bīrūnī records this testimony in his great book on India.¹¹⁷ The Arabs transmitted to the west the so called Hindu numerals and decimal system and the simpler algebraic and trigonometrical processes, but ignored the use of

---

¹¹⁶ *Civil Services Chronicle*, p.125.
negative quantities and the higher algebra of indeterminate equations which they do not appear to have understood.\textsuperscript{118}

**Bhāskara I**

Little is known about Bhāskara’s place of birth, parentage or private life. He seems to have been forgotten after sometimes in the North and only recently has he come to be known there again.

In the South, on the other hand, Bhāskara I and his works have been well-known amongst astronomers. In Kerala he has always been widely known amongst astronomers as the interpreter of Āryabhatta and next only to him in importance. It is in Kerala that his works are extent and his commentators like Govindasvāmin, Sankaranārayana, Parameswaran and Narayana are all astronomers hailing from this part of the country.\textsuperscript{119}

**Date of Bhāskara**

There are controversies regarding the date of Bhāskara. The scholars were of different views about it. Some scholars regard Bhāskara as the direct pupil of Āryabhatta who wrote the Āryabhattiya in A.D. 499 but others consider that Bhāskara could not have been a direct pupil of Āryabhatta.

\textsuperscript{118} A. L. Basham, *op. cit.*, p. 156.
\textsuperscript{119} T. S. Kuppanna Sastrī and T. Chandrasekharan (ed.), *op. cit.*, p. xii.
From the evidence in his Bhāsyā on the Āryabhaṭiya and from the date of Bhāskara’s *Laghubhāskariya*, which was composed 23 years after the composition of the Āryabhaṭiya, it can be concluded by fixing the upper limit to Bhāskara’s date at A.D. 550 and the lower limit may be fixed as A.D. 628, the date of Brahmagupta’s *Brahmasphuta Siddhānta* from the following considerations\(^{120}\) that he could be the grand pupil of Āryabhaṭa, redactor and commentator, who is perhaps, the best authority in the matter, on account of his chronological proximity, besides being a propagator of the Āryabhata school.\(^{121}\)

**Bhāskara and his works**

The *Mahabhāskariya* is an important work in Indian astronomy written by Bhāskara I who must be distinguished from the later and well-known Bhāskaracārya II, author of *Lilavati, Bijaganita* and the *Siddhānta Siromani* (A.D. 1150). Bhāskara I has written three works, the *Mahabhāskariya*, the *Laghubhāskariya* and a Bhāsyā on the Āryabhattiya. He seems to have intended the *Mahabhāskariya* as an exposition on the Āryabhattiya, as well as an independent work. The *Laghubhāskariya* is an epitome of the *Mahabhāskariya*.

\(^{120}\) *Ibid.* p. xvi.

\(^{121}\) S. A. S. Sarma, *op. cit.*, p. 62.
The real name of Mahabhāskariya

Though popularly known by the names Mahabhāskariya and Brhad-Bhāskariya, the name intended by the author to the work is Karmani bandha, 'a treatise on astronomical calculations'. Whereas his Āryabhattiṇya - Bhasyā is called Brhat-Karmani bandha to distinguish it from the Laghu-Karmanibandhu used with reference to the third work of Bhāskara, the Laghu-Bhāskariya.\(^{122}\)

The school of Āryabhatta

Though Bhāskara I was not a direct disciple of Āryabhatta, it is certain that he belonged to the school of Āryabhatta and was one of its important exponents.\(^ {123}\) That Bhāskara identified himself with this school is quite apparent. He refers to Āryabhatta in his Bhasyā as "our preceptor", Asmakamacharya, in several places. When in one place he says, "For us the four quarters of the Yugas are equal", asmakam punāh yuga patha sarva ēvathulayaha, he identifies himself with the teacher and his school.\(^ {124}\)

As far as the place from where Bhāskara I hailed and settled down in later life to write his works, there is no sufficient evidence to state anything definitely. While K. S. Shukla is of the opinion that there are, however,

\(^{122}\) T. S. Kuppana Sastri and T. Chandrasekharan (ed.), op. cit., p. xi.

\(^{123}\) S. Parameswaran, Āryabhatta, loc. cit., p. 205.

reasons to believe that Bhāskara I belonged to the Aṣmaka country and that he lived and taught at Valabhi in Surastra (modern Saurastra or Kathiawar) where he wrote his commentary on Āryabhatīyam, scholars like A. N. Singh of Lucknow hold that there is sufficient justification to state that Bhāskara was a native of Kerala.

Another opinion runs as follows: ‘stray references to his (Bhāskara I’s) works appear to indicate his association with Surastra (Western India) and Aṣmaka (South India, probably Kerala). It is possible that he was a native of either of these two regions and migrated to the other’. But there are no accurate evidences to prove these facts.

Bhāskara I earned great name and fame as a teacher of astronomy and his works continued to be studied in South India and several commentaries came to be written by South Indians especially Keralale - Scholiasts such as Govindasvāmin (800-850 A. D.), Sankaranārayanan (825-900 A. D.), Udayadivākaran (11th century) and Parameswaran (1360-1455 A. D.).125 The achievements of Āryabhatta, Varāhamihira, Brahmagupta and Bhāskara I are monumental.

Bhāskara II

Bhāskara II was a mathematician. In India indeterminate analysis reached its zenith in Bhāskara II. He obtained whole number values of $x$ and $y$ which satisfy the equation $ax \pm by = c$.

Indeterminate equations of the second degree in the forms;

$$ax + by + c = xy$$
$$and \ ax^2 +c = y^2$$

had already been investigated by Brahma gupta, but the solution of the general equation.

$$ax^2 + bx + c = y^2$$

by the chakravāla or cyclic method, was effected by Bhāskara II in a manner which has perpetuated his name for all time in the history of the theory of numbers. It is salutary to remember that Bhāskara II made these advances around the middle of the twelfth century, independent European investigations, of the seventeenth and eighteenth centuries did not reach completion until about 1770, with the work of Euler and Lagrange.

The delightful Lilavati and Bijaganita, which form part of the Siddhānta Siromani of Bhāskara II, have been widely used since their composition. A Persian version of Lilavati appeared in 1587 on the orders
of Akbar and one of Bijaganita in 1635 for Shāh Jahān. Lilavati was later rivalled by the Ganita Kaumudi, composed in 1356 by Nārāyana, a work notable for its treatment of magic squares. Indian interest in magic squares is reflected in Siamese mathematics of the seventeenth century.\textsuperscript{126}

Little, if any, astronomical activity existed in India over the next five centuries until Jai Singh (1686-1743) performed the incredible feat of building five observatories and making accurate observations with them in a little less than four decades. These institutions contain enormous instruments of masonry, many of which were invented by Jai Singh himself such as jai prakās and ram yantra and samrāt yantra, the semi diameter etc. and were meant to mutually confirm and check the observations made. Though magnificent in concept, they were seldom used after Jai Singh, and with the new era of telescope technology already a hundred years old, they retreated rapidly into obsolescence.\textsuperscript{127}

In astronomy the Muslim tradition of instrumental technology survived in India until the middle of the eighteenth century. The astrolabe, which has been lovingly perfected by generations of Persian and Arab craftsmen and was again executed in fine workmanship by the family of ‘Īsāb’ Allahabad in Lahore in the reign of the Mughal Emperor Jahāngir

\textsuperscript{126} A. L. Basham, \textit{op. cit.}, p.157.
\textsuperscript{127} Priyaranjan Ray and S. N. Sen, \textit{op. cit.}, p. 261.
was used by the astronomers in the service of the Maharaja Sawai Jai Singh II (1686-1743) at his observatories in Delhi, Jaipur, Ujjain, Varanasi (Benares), and Mathura. Though Jai Singh’s principal astronomer was the Hindu Jagannath he made full use of European and Islamic ideas. In particular his massive masonry quadrants and dials, constructed to attain maximum accuracy, in the absence of the telescope in India.\textsuperscript{128}

Though with Bhāskara II ended the great era of mathematics in North India, Kerala continued to make its mark in the field. The achievements of some eminent astronomers of Kerala have been particularly remarkable as is evinced by the numerous contributions of various scholars in astronomy and astrology.\textsuperscript{129}

\textsuperscript{128} A. L. Basham, \textit{op. cit.}, p.158.
\textsuperscript{129} N. Narayanan Namboodiri (ed.), \textit{Karanamrtam}, University of Kerala, 1975, p.i.