

IDENTIFICATION OF AŚMAKA*

The Aśmaka is referred to by Bhāskara-I as the South Indian Jain settlement around Śrāvanabelgola (12°51'N, 76°29'E) and Dharmasthala (12°53'N, 75°23'E) – a place having the name Aśmaka in Jaina canons because of the great stone monoliths at the place. Verse 9 of Kālakriyā giving the Jaina 12-fold division of Yuga, Verse 5 of Daśagītikā which speaks of Bharata, the first Universal emperor of Jains, Verse 11 of Gola referring to *Nandana-vana* and *Meru* representing terminology borrowed from the *Tiloyapannatti* of Jains, Verse 1 of Gaṇita, and verses 49 & 50 of Gola reflecting, Brahmāḥ the primordial diety of Jains, and use of Kali Era hint to distinct signature of Āryabhaṭa for the first time in South India.

Effort has also been made to review the major conclusions on the homeland of Āryabhaṭa and the controversy on the identity of Aśmaka.

Introduction

When it comes to the native place of Āryabhaṭa, confusion prevails with opinion divided between Kerala (Aśmaka of disputed identity) and Kusumapura (near modern Patna). Scholarly opinion lately is in favour of Kusumapura as we can find in the *Āryabhaṭīya*¹, published by the Indian National Science Academy, latter half of Gaṇita, verse 1 reads as:

Āryabhaṭstviha nigadati kusumapurebhyarcitam jñānam.

It means “Āryabhaṭa sets forth here the knowledge honoured at Kusumapura” which is taken by everyone including KV Sarma, the doyen of the Kerala tradition of scholars as referring to the location of Āryabhaṭa. Further in the discussion Shukla and Sarma aver that ‘we can conclude without any shadow of doubt that Āryabhaṭa I flourished at Kusumapura or Pāṭaliputra...’ and also quotes Bhāskara-I and Nīlakaṇṭha to suggest that Āryabhaṭa was born in Aśmaka Janapada. We can find the same idea receiving elaborate discussion in the *Āryabhaṭīya*, second volume² published by INSA with the commentary of Bhāskara-I and Someśvara.

* Contributed by **K. Chandra Hari**, B6-103, ONGC Colony (East), Chandkheda-382424, Gandhi Nagar (Dist), Gujarat

*A Concise History of Science in India*³ published by the Indian National Science Academy in 1971, just a few years prior to the *Āryabhaṭīya* edition of Shukla and Sarma in fact gives a contradictory account as below:

“...scholars have thought for a long time that Āryabhaṭa was either born in Kusumapura or lived and taught in that great city of ancient India. Such a view now appears untenable in the light of recent studies on the works of Bhāskara-I and his commentators and also of the medieval commentators of Āryabhaṭa. In these works, Āryabhaṭa is frequently referred to as an *aśmaka*, that is one belonging to the Aśmaka country which is the name of a country in the south, possibly Kerala... the fact that commentaries of and works based on *Āryabhaṭīya* have come largely from South India, from Kerala in particular, certainly constitute a strong argument in favour of Kerala being the main place of his life and activity”

But the scholarly opinion is strongly in favour of a Kusumapura origin of Āryabhaṭa and his works as may be noted from the account of Ifra Georges⁴ as well:

“A veritable pioneer of Indian Astronomy, Āryabhaṭa is without doubt one of the most original, significant and prolific scholars in the history of Indian science. He was long known by Arabic Muslim scholars as *Arjabhad* and later in Europe in the middle Ages by the Latinized name of *Ardubarius*. He lived at the end of the 5th century and the beginning of the sixth century AD, in the town of Kusumapura...”

Sastry, one of the doyens of last generation in the field of Indian Astronomy and history of astronomy, has discussed the issue on the following lines:⁵

“As far as astronomical works are concerned, it seems that the Kerala country was the seat of its development in the South. It is all based on the *Āryabhaṭīya*, with or without corrections called the *bījas*... How Āryabhaṭa came to be connected with the Kerala country is yet to be explained. He is called *Aśmaka* (i.e. one born in the *Aśmaka* region) and some say that an early name of the erstwhile princely state of Travancore was *Aśmaka* (Apte’s Dictionary). But many say that the region near the Vindhya was called the *Aśmaka* country...”

Sarma⁶ in his magnum opus, *Contributions to the study of the Kerala School of Hindu Astronomy and Mathematics* (1977) describes Āryabhaṭa as having flourished at Kusumapura (modern Patna) and explains that the system of Āryabhaṭa declined in North India owing to the criticisms from later authorities like Brahmagupta, Varāhamihira and Śrīpati. He also observes that with the

popularity gained by the great works of Bhāskara-II, the Āryabhaṭa system was practically effaced from North India and not even a manuscript or a North Indian commentator of Āryabhaṭa appeared in the scene after Bhāskara-II. Sarma has also spoken of the legends prevailing in Kerala related to Sanskritization of vernacular place name Koṭuññallūr which was the place of an observatory in ancient times. Koṭuññallūr or either of the Kallur names can be an equivalent to *aśmaka* (hard black stone) and legends which make Āryabhaṭa a native of Kerala had been in circulation since ancient times. He is believed to have propagated his teachings at Kusumpaura in Northern India.

Shukla's discussion on the issue supported by Sarma who had been the greatest authority on Kerala's astronomical tradition and treatises almost nails the conclusion⁷ that Āryabhaṭa was a native of Kusumapura. On an occasion when the present author had discussed the issue with Sarma he did point out that the following some popular speculations early researchers held some notions like Aśmaka referred to by Bhāskara-I, as sanskritized vernacular place name, Koṭuññallūr. But subsequently references to ancient Tamil literature suggested that the original place name of Koṭuññallūr was Koṭumkolūr and not Koṭumkallūr as required for being the vernacular equivalent of Aśmaka viz. *koṭum-kal*.⁸ Given the background of the sanskritization of vernacular place names as we find illustrated with *Asvattha-grāma* (Ālattūr) of Parameśvara in 1450 AD, and numerous such innovative names like Śukabhāvukam for Tattamaṅgalam, Śilaviṇam for Pārakkaṭu etc speculation still exists that Aśmaka is the sanskritization of Kallūr, a name with which different places are existent since ancient times in Kerala. Koṭakal or Koṭakallūr⁹ which had a prehistoric stone memorial that gave name to the place became Tirunāvāya in later times and there Mahāmagham used to be held for 12-yearly deliberations on Śāstras and is associated with Kerala astronomical tradition as early as 683 AD, the times of Haridatta, popular in vernacular language as Nāranathu Bhrānthan¹⁰ through legends. All places in Kerala have got Śiva temples and as such the Śaiva signature that we see in Bhāskara-I can be explained irrespective of which Kallūr we consider as the equivalent of Aśmaka. Koṭakal is said to have a nearby place Kallūr associated with a Śiva temple and presently it falls in the Kuttippuram tāluk. Based on these speculations many people have taken Āryabhaṭa to be a native of Kerala despite the scholarly assessment referred earlier and many websites portray him accordingly as a Kerala Astronomer.¹¹ A very concise brief about the life and works of Āryabhaṭa is available in *Encyclopedia Britanica*¹² and its says:

“Āryabhaṭa I or Āryabhaṭa the Elder to distinguish him from a 10th – century Indian mathematician of the same name, he flourished in Kusumapura-near Pāṭaliputra(Patna), then the capital of the Gupta dynasty-where he composed at least two works, *Āryabhaṭīya* (c. 499) and the now lost *Āryabhaṭasiddhānta*. *Āryabhaṭasiddhānta* circulated mainly in the northwest of India and, through the Sasanian Dynasty (224-651) of Iran, had a profound influence on the development of Islamic astronomy. Its contents are preserved to some extent in the works of Varāhamihira (flourished c. 550), Bhāskara I (flourished c. 629), Brahmagupta (598 c. 665), and others. It is one of the earliest astronomical works to assign the start of each day to midnight. *Āryabhaṭīya* was particularly popular in South India, where numerous mathematicians over the ensuing millennium wrote commentaries” (sic).

Above references amply illustrate the debate going on in respect of the place of origin and astronomical observations of Āryabhaṭa and the prevailing conclusions are speculative in nature. It also becomes apparent that the 1500 year old tradition consisting of a galaxy of great astronomers as well as the modern scholarship (at least since the Publication of Parameśvara’s commentary on *Āryabhaṭīya* by H. Kern¹³ in 1874) studying the works of Āryabhaṭa could not find any astronomical or socio-cultural data that enables identification of his native place or place of observation.

The confusion prevailing in respect of the homeland of Āryabhaṭa remains all the same despite researches of scores of years since the days of Dikshit who summarized the state of knowledge as existed in 1896 in the following words:¹⁴

“quotations from *Āryasiddhānta* are not found in astronomical works which were compiled in Maharastra and Varanasi after Śaka 1400...Dr. Kern has published an *Āryabhaṭīya* on the basis of three manuscripts obtained by him. All these manuscripts are written in the Malayalam script. This shows that the *Āryasiddhānta* is still known in South India and specially in the Malabar province. The provinces which speak the Tamil and Malayalam dialects follow the almanac computed on solar basis and it belongs to the *Āryapakṣa*... The Vaiṣṇavas are adherents of the *Āryapakṣa*. They form a large part of the population in Karnataka and Mysore. Patna in Bengal (at that time) is believed to be Āryabhaṭa’s place; but there is some doubt about it; because the *Āryasiddhānta* is not at all in use in Bengal...”

Dikshit had no knowledge of Bhāskara-I or his works and was therefore unaware of the Aśmaka connection and the mention of *Āryabhaṭīya* as

Aśmakīya Tantra. It is apparent from the above accounts that the life and work of Āryabhaṭa had a mysterious link to places such as Kerala or Malabar, Aśmaka and Kusumapura and is wanting an explanation that reconcile his connection to these places.

Aśmaka in Jain Literature versus the Aśmaka Country

Confusion as above and the conflict between Aśmaka and Kerala may be resolved by taking a closer look at the Aśmaka as described in Jaina canons. Sukla has discussed the three identifications possible for Aśmaka: (1) Northwest India beyond Gāndhāra, (2) Between Godavari and Mahismati (Indore), and (3) Maharastra, but neither of these places is known to have any astronomical tradition. Had Maharastra been Aśmaka, Bhāskara-II would have definitely described himself as belonging to the same place as Āryabhaṭa and as another *Aśmakīya* like Bhāskara-I and further the records quoted are too scanty to suggest the popularity of such a name as of a political unit of 6th and 7th century, periods of Āryabhaṭa and Bhāskara-I.

Aśmakas known from Greek records¹⁵ of Alexander's expedition is the tribe Assakenoi in the Northwest and the same is referred to by Varāhamihira as quoted by Sukla.

We therefore have to look for alternate explanations to explain the juggernaut of Aśmaka.

Ayodhyā and Aśmaka:

A look at the Jain myths on Bharata and Bāhubali alias Aśmakān, the sons of Ṛṣabhanātha suggests that at the root of the Jain conception of India or Jambudvīpa is the division of the country into a Northern part called Ayodhyā and southern one called Aśmaka. The following legend is noteworthy in this context:

“Bāhubali, the first Jaina saint to attain liberation in this ‘*apasarpinī kā la*’, i.e., the descending half arc of time, was the son of Lord Ṛṣabha, the first Jaina Tīrthāṅkara, who flourished at the dawn of civilization and taught mankind the first lessons of a cultured life. Lord Ṛṣabhadeva, the son of Nābhirāja and Marudevi, was a patriarch king of Ayodhyā. Lord Ṛṣabhanātha had many sons, among whom Bharata and Bāhubali were very prominent. Bharata was the crown-prince and he succeeded his father to the throne of Ayodhyā. By his prowess Bharata became the first universal monarch and due to his profound impact on the country, India

came to be known as “*bhāratavarṣa*”, i.e., the land of Bharata. Bāhubali was given the kingdom of ‘Aśmaka’ from south India which he ruled from its capital seat at Poyyanapura. In this way after dividing his kingdom among his sons, Lord Ṛṣabhadeva retired to the Himalayas and adopted the Jaina ascetic way of life to teach mankind the path of salvation...”

Legend goes on to state that Bharata in his attempt to become the Cakra-varty (holder of the discus attempted to conquer Aśmaka in the South but got defeated in all three non-violent modes of fight and Bharata took to the forests. But Bāhubali who was overcome by grief at the behavior of his elder brother renounced the Aśmaka kingdom for Bharata and thus the whole of India including Aśmaka became *Bhāratavarṣa*. Bāhubali took to penance in Śrāvanabelgola and attained liberation and it is that part of the country which is known as Aśmaka in Jain records.

Śrāvanabelgola and Aśmaka

Above identification of Aśmaka as South India in general or the area neighboring Śrāvanabelgola receives historical support from the following facts:

1. Migration from Pāṭaliputra (Kusumapura) and settling of Bhadrabahu and Chandragupta Maurya at Śrāvanabelgola in 3rd century BC.
2. Stone monoliths at the place gave the name Aśmaka (meaning stone monolith) in early times to the country surrounding Śrāvanabelgola and Dharmasthala.
3. The first inscriptional record of Kali Era and the year 3735 is found in the Aihole inscription¹⁶ by Calukya King Pulikesi-II who was an ardent Jina devotee and the inscription itself begins with the praise of Jinendra. This supports the association of Āryabhaṭa with the Jain tradition and the absence of the use of Kali Era before 634 AD in other places in India especially North.
4. In the long list of Kingdoms and settlements (*Janapada*) subdued by Pulikesi-II (who was a contemporary of Bhāskara-I, 629 AD, Nala, Maurya, Kadamba, Kālacūri, Revatī, Vanavāsi, Gaṅgā, Alupa, Konkana, Puri, Lāṭam, Mālava, Gurjaram, Kaliṅgam, Kosalam, Mahārāṣṭrakam, Piṣṭapuram, Kanchipuram, Cola, Pandya and Kerala – there is no mention of any political unit or *Janapada* called Aśmaka in 7th century, anywhere near Godāvarī. The speculations about Aśmaka can be laid to rest if it is accepted that Aśmaka meant a place of stone monoliths and the world’s largest stone statue standing at Śrāvanabelgola attests this fact.

5. Legendary name of Aihole as Āryapura suggests the possibility that the town may have been originally named after Āryabhāṭa or may be the place where he may have attained liberation later in his life.

Jain Tradition and Āryabhāṭīya

Discussion on Aśmaka receives further support from Āryabhāṭīya as explained below:

Yuga and Divisions^{17,18}

*utsarpiṇī yugārdhaṃ paścādapasarpiṇī yugārdhaṃ ca |
madhye yugasya suṣamā 'davante duṣṣamendūccāt || (Kālakriyā 9)*

“The first half of a yuga is Utsarpiṇī and the second half Apasarpiṇī. Suṣamā occurs in the middle and Duṣṣamā in the beginning and end. And their interval is fixed by the revolutions of the Apogee of the Moon”.

Shukla has observed that this terminology is in conformity with the teachings of the Jaina canons. As he has shown, the verse implies a 12 fold division of Mahāyuga with 3 each Duṣṣamā divisions as the beginning and end triplets of the Mahāyuga and 3 each as the middle divisions in a pattern like :

Mahāyuga = Utsarpiṇī + Apasarpiṇī = DDDSSS + SSSDDD (D = Duṣṣamā and S = Suṣamā) = 6 + 6 = 12 parts

In terms of the number of solar years, this means,

$$4320000 = 360,000 \times 12;$$

$$\text{Utsarpiṇī} = \text{Apasarpiṇī} = 2160000 \times 2;$$

Āryabhāṭa, as criticized by Brahmagupta, had altered the Kṛtādi Yuga cycle in the ratio 4:3:2:1 (as available in the Smṛtis and scriptures of the Brāhmins) to a division of 4 equal parts of 1080000 solar years = 360,000 x 3 and thus the Kaliyuga or the 4th Pāda of the Mahāyuga was Apasarpiṇī and Kaliyuga as ordained in the Jain canons.

In fixing the intervals of the Ds and Ss, Āryabhāṭa says that it must be on the basis of the revolutions of the Apogee of Moon as it is the only mean longitude having no abraded Yugas and Apogee of Moon have 488219 complete revolutions only in 4320000 years.

Apasarpinī Kaliyugādi in Jain tradition : Here a very important question encounters us as to what is the significance of Apasarpinī – Kaliyugādi in the Jain tradition? What is the factor that inspired Āryabhaṭa to modify the Brāhmanical Yuga cycle for making it conform to the Jain tradition?

Answer to this question can be found in the *Āryabhaṭīya*.

*kāho manavo dha manuyugāḥ śkha, gatāste ca, manuyugāḥ chūna ca/
kalpāderyugāpādā ga ca, gurudivasācca bhāratāt pūrvam || (titika 5)*

Even Bhāskara-I, the first known commentator whose works have survived the last 1400 years, and the Indian astronomical tradition since the time of Āryabhaṭa has construed and interpreted this verse wrongly with the ending words as '*Bhāratāt pūrvam*' because of the Brāhmanical bias to see the Mahābhārata war in the above verse. According to Mahābhārata the Kaliyuga as per the Smṛtis began 36 years after the Kurukṣetra war when Dvārakā got engulfed by the sea. From this event the Pāṇḍavas could understand that Kaliyuga has begun and the exit of Kṛṣṇa from the world as forecasted by Gandhārī that Kṛṣṇa and his Yādava clan will be destroyed 36 years after the war at Kuruksetra, How can then Āryabhaṭa say that the Kali Era began before the Bhārata war?

In fact the correct reading of the verse, *Bhāratāt pūrvam* - i.e. before the time of Bharata, the son of Ṛṣbhanātha Tirthankara from whom Bhāratavarṣa received its name. Bharata is the first universal emperor of Jains and Yugādi marked his accession to the throne when Lord Ṛṣbha retired to the forests. It must be noted here that according to Jain legends Bāhubali the brother of Bharata was the first saint to attain liberation in the *Apasarpinī kāla* coinciding with Kaliyuga and hence the time of Yugādi was of importance to Aśmaka where Bāhubali did penance after enthroning Bharata. Bharata in Jain legends symbolized *Apasarpinī yuga* by his wish to conquer the material world and become Cakravartī which got thwarted by saintly Bāhubali who achieved liberation.

It may be interesting to note that at Camravattam the place identified to be that of Āryabhaṭa (10°5'N, 75°45'E) the deity installed is Śāsthā who too is regarded as a deity of Kaliyuga (*Kaliyugavarada*) and in his later legends of Ayyappa he is portrayed as a Prince who relinquished the kingdom and retired to forests for penance, in the same mould as the ancient legend of Bāhubali.

Influence of the Jaina text *Tiloyapannatti*¹⁹ is very clear from the Yuga cycle given as per Jain canons and as such Āryabhaṭa had no reasons to refer to

the Bharata war as a chronological marker in the Jain cycle of *Yugas* or definition of *Mahāyuga/Kalpa*. In fact, it will be a contradiction if we are to presume that the great astronomer who rejected the purānic, epic and smṛti based *Yugas* shall resort to define the *Yugādi* based on such Brāhmānical treatises.

The Āryabhaṭa Meru and Nandana-vana : (Golapāda Verse 11) renders additional illustration of the Jain influence on Āryabhaṭa. Nandana and Meru together form the topic of description in *Tiloyapannatti*²⁰ and such descriptions is not found in other treatises which arose out the Brāhmānical tradition.

Golapāda Verses 49 and 50:

śadassadjñānasamudrāt samudhṛtam brahmaṇaḥ prasādena |
śatjñānottamaratnam mayā nimagnam sva mati nāva || (Gola pāda : 49)

“By the grace of Brahmā, with intelligent work I have made this knowledge of manifested Universe to rise from the Ocean of the knowledge of the manifested (*śat*) and un-manifested (*aśat*). Brahmaṇaḥ referred to here is the primordial Lord of Jain tradition who presides over the manifested and un-manifested and who is regarded as taken the Avtār as Ādinātha or Ṛṣbhanātha in Jain legends.

The former half of the concluding verse of *Āryabhaṭīyam* (*Āryabhaṭīya nāmnā pūrvam svāyamabhūvam sadā satyam*) also refers to the same primordial Lord of the Jains as self-born (Svāyambhu) who is eternal and the knowledge or truth that descended from him.

In the Brāhmānical religion, Lord Śīva was the custodian of knowledge as Svāyambhu and the fact may be understood from the praise showered by Bhāskara-I and Brahmagupta on Śīva in the introductory verses of their works. Āryabhaṭa’s invocation of Brahmā, perhaps the first reference (and scanty reference in later times in emulation of Āryabhaṭa) to Brahmā in an astronomical work arose out of the influence of Jain canons. Gaṇita (verse 1) too begins with the invocation of Brahmā and planets and obviously the reference is to primordial deity of the Jains from whom the Planets and the Creation evolved.

Role of Jains in the Development of Mathematics in India

Jain tradition boasts of antiquity which is mind boggling, like Ṛṣbhanātha living 60,000 years and also legends place 23rd Tirthaṅkaras before the time of Mahāvīra in the 6th century BC. Scholars have expressed the opinion that the Indus Civilization may have been the ancient source of Jain religion and the sect

may have played a significant role in the development of Brāhmī numerals and zero. J J O'Connor and E F Robertson²¹ has given a sum up of the history of Indian Mathematics and the following notions that represent the present state of researches support the association of Āryabhaṭa with Jains of Śrāvanabelgola and their southerly extension to Kerala in 6th century AD:

1. The main topics of Jain mathematics in around 150 BC were: the theory of numbers, arithmetical operations, geometry, operations with fractions, simple equations, cubic equations, quadratic equations and permutations and combinations. More surprisingly the Jain developed a theory of the infinite containing different levels of infinity, a primitive understanding of indices, and some notion of logarithms to base.
2. By about 500 AD the classical era of Indian mathematics began with the work of Āryabhaṭa. His work was both a summary of Jain mathematics and the beginning of new era for astronomy and mathematics. His ideas of astronomy were truly remarkable. He replaced the two demons of Rāhu, the Dhruva Rāhu which causes the phases of the Moon and the Parva Rāhu which causes an eclipse by covering the Moon or Sun or their light, with a modern theory of eclipses. He introduced trigonometry in order to make his astronomical calculations, based on the Greek epicycle theory, and he solved with integer solutions indeterminate equations which arose in astronomical theories.
3. In the discussion on the Mathematics of the post Vedic period, Bag AK has brought out the following facts:²²
 - (a) Indigenous development of Jaina Mathematics by scholars such as Siddhasena, Bhadrabāhu etc who were not mathematicians.
 - (b) Arithmetic and *Jyotiṣa* had been considered as one of the main compliment of a Jaina saint.
 - (c) Kusumapura school had been in existence probably since the time of Bhadrabāhu (300 BC) and Āryabhaṭa perhaps took his lesson in the fifth century AD.
4. Continuing his discussion Bag has spoken about the Schools of Ujjain and Mysore²³ linking the same with Bhadrabāhu and his migration to South. His 1979 work is categorical in stating that Bhaskara-I's reference to *Āryasiddhānta* as *Aśmaka-tantra* also testifies that the work was written in Aśmakadesa in Kerala.
5. Socio-religious history of Kerala and Karnataka and South India in general speaks of replacement of Jain and Buddhist settlements by Vaiṣṇavas in later times. Dikshit²⁴ has spoken of the solar calendar followed by Vaiṣṇavas of Karnataka, Kerala and Tamilnadu – a consequence of the replacement of Jain tradition by Vaiṣṇavas and their adoption of the *Āryasiddhānta* for calendar purpose. This also explains the adoption of sidereal Greco-Babylonian calendar of Āryabhaṭa by Vedic Brahmins who had been following a seasonal calendar as we see in *Vedāṅga Jyotiṣa*.

6. It may not be far fetched to think that it was the mixed influence of Jain and Greek influence that inspired Āryabhaṭa to have the scientific division of the treatise into Gaṇita, Kālakriyā and Gola of the total 108 verses (*Āryaṣṭasāta*) and the Dasagītika which gave mean motion of the planets.

Above conclusion on the history of Indian Mathematics renders additional support to the Jain links of Āryabhaṭa and his location at Camravattam where Bahubali, the legendary ruler of Aśmaka may be found installed and worshipped even today as Śāsta (in its Brahmnic form). Camravattam stood very close to the ancient port of Ponnani which had been an Arab trade centre since pre-historic times and thus Āryabhaṭa had the chance of being access to Alexandrian and Babylonian astronomical resources. Greek connection through Arab traders and Greek knowledge are a certainty as Āryabhaṭa created an entirely new science reforming the Jain science as existed before him, from which he drew only the part necessary to establish the distant epoch required for the computation of mean longitudes.

Comparing the latitudes and longitudes of Camravattam (10°51'N 75°45' E) with those of Śrāvanabelgola and Dharmasthala suggests that the places were close to each other as to be treated as parts of the same country Aśmaka – a name which owed its origin to the natural stone monoliths out of which the statues got carved out under Jains.

Development of Sines and Cosines in Kerala

It is well known that Āryabhaṭa is the first astronomer who has made use of the sines and cosines replacing the chords of Greek astronomers. But no explanation was ever given as to how Āryabhaṭa arrived at the novel use of the chords as Rsines which later became characteristic of Indian Astronomy. According to legends prevailing in Kerala related to the reviser of *Āryasiddhānta* viz Haridatta, the sines and cosines were developed in Kerala from the analogy of rolling a stone uphill by drawing the contrast of achieving height with difficulty and then the foot is achieved with ease by allowing the stone to roll down.

Sine = Height/Hypotenuse and Cosine = Base/Hypotenuse. In the typical circle of radius OA=R= OB separated by arc α and M is the perpendicular from B on OA, we can write:

$$\text{Sine } \alpha = \text{BM/OB} = \text{BM/R}, \text{ or } \text{BM} = \text{R} * \text{Sine } \alpha = \text{Height.}$$

$$\text{Cos } \alpha = \text{OM/OB} \text{ or } \text{OM} = \text{OB} * \text{Cos } \alpha = \text{R} * \text{Cos } \alpha = \text{Base}$$

Also we know that the 24 sines were chosen to have the first sign equal to its arc of $03^{\circ}45'$ and the successive ones could be derived using the method of Āryabhaṭa. Deriving these 24 Rsine values for α up to 90° was difficult as the slope increased or angle increased but once the 24 Rsines were determined, the cosines could be easily derived. Achieving the height was difficult like rolling a stone up hill but once the height or $R \cdot \text{Sine } \alpha$ is achieved, it was easy to derive the base or $R \cdot \text{Cos } \alpha$ was easy by the rule of compliment. Also, it is noteworthy that height is achieved by means of the Hypotenuse along which the stone is rolled up to height. But once the height is achieved i.e. $\text{Sine } \alpha$ is obtained it was easy to have $R \cdot \text{Cos } \alpha$ or the Base by the rule of compliment and thus analogy was drawn for the process of a stone rolled up the hill to achieve the height and then left to roll down with ease to reach the base.

Legendary story as above prevailing in Kerala of Haridatta rolling stones up on the hill and leaving them to roll down for illustrating the origin of sines and cosines point towards the fact that the use of sines came into existence in Kerala for the first time, introduced by Āryabhaṭa.

Conclusions

It is apparent from the above that: the hypothesis on the heliacal phenomena of Canopus viz Camravattam ($10^{\circ}51'N$, $75^{\circ}45'E$) as the home land of Āryabhaṭa, receives additional support from the social-cultural factors related to the Jaina tradition in Kerala and South India.

Aśmaka referred to by Bhāskara-I is the South Indian Jain settlement around Śrāvanabelgola ($12^{\circ}51'N$, $76^{\circ}29'E$) and Dharmasthala ($12^{\circ}53'N$, $75^{\circ}23'E$) – receiving the name Aśmaka in Jain canons because of the great stone monoliths at the place.

Legendary and symbolic account of the derivation of sines and cosines in analogy with the rolling up of a stone to achieve height and then leaving the same to roll down in ease is explained as evidence for the origin of the use of sines with Āryabhaṭa in Kerala.

A number of circumstantial evidences from Āryabhaṭa and the Jain accounts regarding Jaina 12 fold division of Yuga, Bharata the first Universal emperor of Jains, Nandana-vana and Meru, Brahmāh the primordial deity of Jains referred to by Āryabhaṭa, and the use of Kali Era in both *Āryabhaṭīya* & the Aihole

inscription of the Cālukya King Pulikesi-II suggesting Aihole as Āryapura after the name of Āryabhata have been adduced in support.

Notes & References

1. Kripa Shankar, Shukla, K.V. Sarma, *Āryabhaṭīya*, pp. xvii-ixx, 1976, Indian National Science Academy, New Delhi-2.
2. Kripa Shankar, Shukla, *Āryabhaṭīya* with the commentary of Bhāskara-I and Someśvara, p. xxv-xxviii, 1976, Indian National Science Academy, New Delhi-2.
3. D.M. Bose, S.N., Sen, B.V., Subbarayappa, *A Concise History of Science in India.*, p.93, Indian National Science Academy, New Delhi-2
4. Ifrah, Georges, *The Universal History of Numbers-II*, p.182., Penguin Books India, 2005, New Delhi.
5. TSK. Sastray, *Mahābhāskarīya*, V. 4, p.251, Madras Government Oriental Series, 1957.
6. K.V. Sarma, *Contributions to the study of the Kerala School of Hindu Astronomy and Mathematics*, Vol. I (1977), Doctoral Thesis submitted to Panjab University, pp.6-8.
7. Ibid, p.xviii. "Hence we can conclude without any shadow of doubt that Āryabhata-I flourished at Kusumapura or Pāṭaliputra in ancient Magadha or modern Patna (long. 25°37'N., lat.85°13'E)" (sic). (Type error has exchanged the latitude and longitude, correct reading is Lat.. 25°37' N and Long. 85°13'E). Title page of the book gives the information that the *Āryabhaṭīya* critically edited with introduction, English translation, notes, comments and indexes have been done by Kripa Shankar Shukla in collaboration with KV Sarma who had his doctoral dissertation running over 2000 pages on the Kerala astronomical tradition.
8. Sarma, Page 8, footnote, Reference (4) above. Sarma has also quoted a Malayalam article as reference to the legends prevailing in Kerala.
9. Information shared on 6th April 2007 while discussing the possibility of Kallur near about Ponnāni-Beypur area where Bhāratappuzha or Nila joined the sea, by Radhakrishnan, C., literary genius of Kerala and Meteorologist, ex-Editor of *Bhāṣapoṣiṇi* and *Science Today* and well known scholar and historian whose magnum opus is the research oriented biographical novel on the life and works of Tunjathezhutachan (1500 AD), the father of modern Malayalam Alphabets.
10. Kutti. Narayanan, *Melannattu*, pp. 276-279, Sangha Sahitya Caritram, (2006) Kerala Bhasa Institute, Trivandrum.
11. <http://www.spacetoday.org/India/IndianAstronomy.html> - "Aryabhatta was born in 476 A.D. at Ashmaka in what today is the Indian state of Kerala. He was sent to the University of Nalanda as a boy to study astronomy". Also the same description may be seen at sites like <http://www.crystalinks.com/indiastronomy.html>. Website http://www-groups.dcs.st-and.ac.uk/~history/Projects/Pearce/Chapters/Ch8_2.html says: "We

can accurately claim that Āryabhaṭa was born in 476 AD, as he writes that he was 23 years old when he wrote his most significant mathematical work the *Āryabhaṭīya* (or Arya Bhateeya) in 499 AD. He was a member of the Kusuma Pura School, but is thought to have been a native of Kerala (in the extreme south of India), although unsurprisingly there is some debate'

12. Quoted from the website which has the same account as in the *Encyclopedia*.
<http://concise.britannica.com/ebc/article-9009749/Aryabhata-I>
13. Kripa Shankar, Shukla, K.V. Sarma, *Āryabhaṭīya*, p.xi of Introduction, Indian National Science Academy (1976), New Delhi-2.
14. S.B. Dikshit, *Bharatiya Jyotisa Sastra*, Vol.II, p.61, Controller of Publications, Civil Lines, New Delhi.
15. D.N. Jha, p. 89, *Early India – A Concise History*, Foundation Books, 2005, New Delhi-2
16. Test of the inscription is available at the site – <http://projectsouthasia.sdstate.edu/docs/HISTORY/primarydocs/Epigraphy/AiholeInscription.html>.
17. p. 95 of Ref (15) above gives detailed explanation and the 12 divisions of a Yuga.
18. LC. Jain, *IJHS*, 12.2 (1977) 139, INSA, New Delhi-2
19. *Ibid.*, p. 139
20. *Ibid.*, p. 142-143
21. http://www-history.mcs.st-andrews.ac.uk/HistTopics/Indian_mathematics.html
22. AK. Bag, *Mathematics in Ancient and Medieval India*, Chaukhambha Orientalia, Varanasi (1979), p. 7.
23. *Ibid.*, p. 12
24. S.B. Dikshit, *Bharatiya Jyotisa Sastra*, Vol. II, p.61, Controller of Publications, Civil Lines, New Delhi.