Eclipse observed by Āryabhaṭa in Kerala

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Identification of the place of Āryabhaṭa as Kerala and more precisely the latitude of 10N51 where the west coast of the Indian subcontinent intercepted the Ujjayinī meridian, had been my recent work on the topic of the history of Indian astronomy. An effort has been made here to examine the veracity of the legends in Kerala, of the eclipse observations by Āryabhaṭa from the sea and the hostile reaction of the Brāhmin orthodoxy to the sea voyage undertaken. The annular solar eclipse on AD *519 August 11 has been identified as the one which made Āryabhaṭa to undertake the sea voyage. Āryabhaṭa's adjustment of the length of the solar year and the parallax correction to find the middle of the solar eclipse have been explained on the basis of the relevant factors of the eclipse observed. Further, it has been shown that he may have utilized a period of nearly two months at Kanyākumāri (Cape Comorin) for observing the horizon phenomenon, taking advantage of the east and west sea horizons available at Kanyākumāri. Possibility of an ancient observatory at Kanyākumāri is suggested, considering certain aspects of the religio-cultural life of the region.*

Āryabhaṭa's adherence to the theory of earth's rotation may have been a product of his observations at Kanyākumāri, where he had the rare observation of sunrise and sunset on either side of the water table.

Verse 48 of Goḷapāda, last of astronomical content, mentioning the phenomenal basis of his work Āryabhaṭīyam is shown to meet with a reflection in the celestial phenomenon that could be observed at Kanyākumāri during the lunations that sandwiched the solar eclipse of AD *519 August 11.*

This present study is intended to supplement my earlier work[1] where I have shown that the place of observation of Āryabhaṭa as may be deciphered from *Āryabhaṭīya* is Ponnāni at 10N51, 75E45, where the coastline of Kerala intercepted the yāmyottaravṛttam of Ujjayinī or Hindu prime meridian. An effort has been made here to explore the veracity of the legend that Āryabhaṭa and his son Devarajan had resorted to observe an eclipse from the sea and had invited the wrath of the orthodox elements and excommunication. Kochhar[2] has supported the legend that prevails of Āryabhaṭa and his eclipse observations in Kerala:

'Now, there is a strong tradition that Aryabhata's birth place Ashmaka was in what is now the south Indian state of Kerala. If this is true (not all scholars agree on this), then Aryabhata could have observed the total solar eclipse of AD 493 January 4, whose path passed through Kerala. Interestingly, *Kerala has a legend that Aryabhata and his son Devarajan were excommunicated from their caste for the double sin of going to the sea and observing the eclipse.* In any case, the legend implies the existence of the practice of eclipse observations' (*sic*).

The eclipse cited by Kochhar is based on the wrong identification of the epoch of Āryabhaṭīya as Kali 3600 (AD 499) in place of the true epoch which, according to the Kerala tradition, reflected in the interpretation of *Āryabhaṭīyam* 3.10 by Haridatta is Kali 3623 (AD 522) or Saka 444 known as Bhaṭābda in the Āryabhaṭan tradition. *Āryabhaṭiyam* records the solar eclipse of AD 519 11 August, which apparently reflects Āryabhaṭa's eclipse observations from the sea. This eclipse, according to *Fred Espenak's Five Millennium Canon of Solar Eclipses: –1999 to +3000* (http://sunearth/gsfc.nasa.gov/eclipse) had the following features (Figure 1).

Annular eclipse of the sun on AD *519 August 11*

Maximum of the annular eclipse 08:20:20 UT = 13:23 Ujjayini LMT.
Gamma = –0.1304; Magnitude = 0.9406.
Location where maximum obscuration of the disc is seen = 08°24N, 75:30E.
Sun's altitude = 83 : 24; Width of annularity at maximum = 222 km.
Duration of annular phase totality = 07 m 14 s.

Location where the maximum obscuration happened (08N24 and 75E30), is just 2° south of the place mentioned above as the location of Āryabhaṭa and also close to the Ujjayinī meridian. As such, no astronomer living at that time in Kerala could have afforded to miss a look at the totality of the eclipse. The fact that Āryabhaṭa cared little for unscientific beliefs is evident from his precept on the rotation of the earth, viz. Prāṇenaiti kalām bhūḥ and as such it is obvious that he may have cared little for the taboo notions that the society carried about the sea voyages and may have certainly ventured into the sea to watch the annulus in full. Excommunication from the Brahmin community of Kerala may be one reason that made his name obscure in the annals of Kerala's Nampūtiri community, who take pride in claiming Bhāskara-I as a Nampūtiri and begins the list of veterans that the community has produced with the name of Bhāskara-I[3].

Also given the above location of maximum obscurity, it was easy for Āryabhaṭa

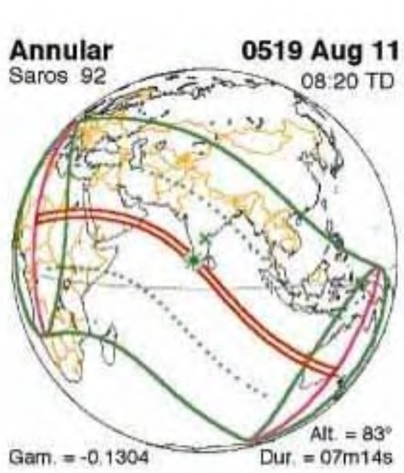

Figure 1. Five millennium canon of solar eclipses (Espenak and Meeus).

to travel by sea over the western sea to 08N24 and the eclipse had its maximum obscurity a little down south of Thiruvananthapuram, 1.5° towards west in the sea.

Now let us have a look at the implications, if any, of the observation of the above eclipse in *Āryabhaṭīyam*.

Salient features of the eclipse of AD 519 August 11 and *Āryabhaṭīyam*

The annular solar eclipse of AD 519 August 11 has remarkable features that it may have been a critical observation for any astronomer who had been living in Kerala then. Important data having a bearing upon the phenomenon are:

Mean new moon

(a) *Āryabhaṭīyam:* Ahargaṇa = 1322379.45334, Sunday 16:53 UMT.
(b) *Sūryasiddhānta:* Ahargaṇa = 1322379.72823, Sunday 17:29 UMT.
(c) Mean new moon according to modern algorithms = Sunday 13:07 UMT, when mean sun = mean moon = 141°03′.
(d) Relevant data in comparison to the modern astronomical values (see Table 1)[4].
(e) Contrasting the Ahargaṇa according to Āryabhaṭa and Sūryasiddhānta at the culmination of the 44,780th lunation, viz. 1322379.45334, Sunday 16:53 UMT and 1322379.72823, Sunday 17:29 UMT, it is easy to realize that the 0.275 days decrement in Āryabhaṭīya is the result of the beginning the Āhargaṇa from sunrise. It is likely that the solar eclipse happening on the prime meridian of Laṅkā–Ujjayinī and concluding in the afternoon may have guided him to formulate the *Audayika siddhānta* or *Āryabhaṭiyam*.
(f) It must be noted here that the midnight system of day-beginning is not at all Indian and even a strong critic of Āryabhaṭa like Brahmagupta, had his *Brahmasiddhānta* following the sunrise beginning of day.
(g) Ārdharātrika, beginning of day as we see in Sūryasiddhānta is a vestige of the Alexandrian connection entering India in the name of the legendary Romaka and Yavanapura, where sunset marked the beginning of the day and correspondingly midnight in the 90° east Ujjayinī meridian. Verse 13 of Goḷapāda of *Āryabhaṭīyam* may be noted in this regard where the legendary cities of the four quarters of the earth (Ujjayinī ± 90°)[5] are mentioned. Romaka and Pauliśa siddhāntas (Pancasiddhāntikā)[6] mention that the day begins at sunset at Yavanapura and so the borrowing of elements in turn demanded the Indian notion of midnight day-beginning.
(h) Āryabhaṭa, being in touch with the Arabs at Ponnāni, may have had access to the Alexandrian sources of astronomy and so set out to create an indigenous system based on the prime meridian of Laṅkā. In his effort, an eclipse falling on the Ujjayinī meridian within just four years of the epoch may have been certainly employed.

True new moon

(a) *Āryabhaṭīyam:* Sunday 14:07 UMT.
(b) *Sūryasiddhānta:* Sunday 15:38 UMT.
(c) Modern astronomy gives true new moon at 12:03 UMT.

It becomes apparent that in terms of the actual phenomenon, *Āryabhaṭīyam* was more accurate than the *Sūryasiddhānta*. Given that the maximum of equation of centre is almost the same in both Āryabhaṭīya and Sūryasiddhānta, the difference in timing between the two is due to the position of the apogee and the ahargaṇa for 44,780 synodic revolutions of the moon since the beginning of Kaliyuga. With the Sūryasiddhānta elements of 1,577,917,828 days for (57,753,336 – 4,320,000) = 53,433,336 lunations, the mean new moon of Sūryasiddhānta was 1.5 ghaṭis or 36 min ahead of the 44,780 synodic revolutions of Āryabhaṭīya. Additional difference of 35 min is due to the difference in the positions of apogee.

Can this extra accuracy be the result of Āryabhaṭa's correction of parameters taking into account this solar eclipse?

The answer to this question can be found by a comparison of the results that both Āryabhaṭīya and Sūryasiddhānta give for the respective epochs, Kali 3600 and Kali 3623 as elapsed. Modification by Āryabhaṭa may be understood by comparing the revolution numbers of *Āryabhaṭīyam* with those of *Sūryasiddhānta* provided below.

Āryabhaṭīya versus Sūryasiddhānta

A comparison of the results for the epochs K3600 and K3623 between the two Siddhāntic models and the modern values is given in Tables 2 and 3.

Comparison of mean longitudes at K3600: Ārya and Sūrya Siddhāntas

It may be noted that the *Sūryasiddhānta* gives only a poor match compared to

Table 1. Major mean elements for AD 519 August 11

	Modern mean longitudes for mean new moon of							
	Āryabhaṭa epoch				Sūryasiddhānta epoch			
Planet	Arya		Modern		Surya		Modern	
Sun	140	58	141	00	140	58	141	1
Moon	140	58	140	21	140	58	140	41
Moon_apogee	*145*	*20*	145	15	140	30	145	15
Moon_node	137	*35*	137	36	133	57	137	35

Table 2. Comparison of mean longitudes of Kali 3600 elapsed: Āryasiddhānta-ahargaṇa: 1314931.25, Sūryasiddhānta: 1314931.523

Planet	Bhagaṇa	Āryasiddhānta	Modern	Sūryasiddhānta	Bhagaṇa
Sun	4320000	0°0′	359:54′	0°0′	4320000
Moon	57753336	280°48′	282:38′	280°48′	57753336
Moon_apogee	488219	215°42′	215:27′	210°54′	*488203*
Moon_node	232226	352°12′	352:00′	348°36′	232238
Mars	2296824	7°12′	06:59′	9°36′	2296832
Mercury	17937020	185°60′	184:01′	197°60′	17937060
Jupiter	364224	187°12′	187:10′	185°60′	364220
Venus	7022388	356°24′	356:28′	352°48′	7022376
Saturn	146564	49°12′	48:23′	50°24′	146568

Table 3. Comparison of mean longitudes K3623: Āryasiddhānta-ahargaṇa: 1323332.2, Sūryasiddhānta: 1323332.475

Planet	Bhagaṇa	Āryasiddhānta	Modern	Sūryasiddhanta	Bhagaṇa SS Col.2+
Sun	4320000	0° 0′	00:04′	0° 0′	0
Moon	57753336	94°42′	94:07′	94°42′	0
Moon_apogee	488219	71°27′	71:24′	*66°37′*	*–16*
Moon_node	232226	267° 6′	267:08′	263°29′	+12
Mars	2296824	89°27′	89:34′	91°52′	+8
Mercury	17937020	5°17′	03:01′	17°22′	+40
Jupiter	364224	165°18′	165:31′	164° 5′	–4
Venus	7022388	135°59′	135:52′	132°21′	–12
Saturn	146564	330° 7′	329:47′	331°19′	+4

Āryabhaṭīya and in the case of the moon's apogee and node, Sūryasiddhānta gives serious discrepancies of the order of 3–4°. But Āryabhaṭa had increased the Bhagaṇas of the moon's apogee by 16 to make it faster and slowed the pace of Rāhu by decreasing the revolutions by 12. These drastic changes in the moon's apogee and node could not have been possible without a remarkable eclipse observation. Comparative data of Kali 3623 given below is more enlightening in this respect.

Comparison of mean longitudes at K3623: Ārya and Sūrya Siddhāntas

At this epoch of Āryabhaṭīya, all mean positions of Āryabhaṭīya are in excellent agreement with the modern values, especially noteworthy is the agreement of the moon's apogee and node with the modern values. This striking correlation at Kali 3623 is unmatched by any Siddhāntic text at any epoch. This may have been accomplished through eclipse observations happening at the vicinity of the epoch, viz. Kali 3623 elapsed.

Criticism of Brahmagupta[7] on moon's apogee in Āryabhaṭīyam

The fact that Āryabhaṭa made drastic corrections to the moon's apogee and node is evident from the criticism of Brahmagupta. Between the Sūryasiddhānta epoch of Kali 3600 elapsed and Āryabhaṭiya of Kali 3623, such a correction could have been done only by eclipse observations and in this context the solar eclipse of AD 519 August 11 must be certainly of great importance.

Salient features of the eclipse and relevance for *Āryabhaṭīyam*

(i) True new moon at 12:03 UMT. Middle of the eclipse is at 12:04 UMT and the parallax is almost zero as the moon just had the upper transit. Eclipse began at 10:07 UMT and ended at 13:53 according to the planetarium software, Skymap pro.

(ii) Here we are concerned more with the techniques of Āryabhaṭa than the precise computation of the eclipse or visibility aspects. Ancient computations are no match to the modern techniques and precision in deriving information on solar eclipse. The question here is whether the computational techniques of Āryabhaṭa in some way reflect the observation of the above eclipse by him?

(a) We may note here that the crux of ancient computation of the stages of the solar eclipse depended upon the ability to account for parallax. In this respect, we see in *Āryabhaṭīyam*, methods cruder than those in Brahmagupta's works and the literature presents us with many discussions on the conflict the latter had with the approximations employed by Āryabhaṭa. However, the Āryabhaṭa tradition gives the correct procedure in *Mahābhāskarīyam*[8] and accordingly, the parallax correction due to the moon for the above eclipse may be derived as given in Table 4.

We have not considered the difference according to the wrong Indian application of parallax to sun and the consequent decrement possible in the above values. Net parallax may be computed using Dṛggati and distances by the traditional formulae. It is sufficient to demonstrate here that the traditional method since the time of Bhaskara-I, had been quite successful in applying parallax correction and computing the middle of the solar eclipse correctly.

Brahmagupta's criticism on the five Rsines employed for computing parallax by Āryabhaṭa has been shown to be wrong by Sharma[9]. In the above example, Āryabhaṭa's method gives satisfactory results comparable to that of Brahmagupta's method. Given the fact that Āryabhaṭa corrected the apogee and node quite appreciably compared to the traditional values as to invite the fierce criticism of Brahmagupta, points towards originality and quite remarkable eclipse observations by Āryabhaṭa to test his algorithm. Similar results as the use of meridian ecliptic point are obtained using Vitribha or nonagesimal and the Rsine of the altitude is computed as the Vitribha Śaṅku.

(b) Going by the prevailing methods, Āryabhaṭa may have expected the eclipse to happen in the afternoon, but it may have begun early and occurred on the meridian of Ujjayinī, facilitating a correction to the day-beginning and solar year. It is doubtful as to whether the locality of maximum obscuration could be computed in ancient times as happening in the sea. Reasons for the young astronomer venturing into the sea may be sought in other factors.

(c) Considering that altitude and zenith distance could be ascertained more accurately against the sea horizon and solar eclipse with totality over the Laṅkā–Ujjayinī meridian had been happening close to the west coast of Kerala, it is likely that Aryabhata did not bother about the taboo notions of the orthodox Brahmin community.

(d) The method followed by Āryabhaṭa to fix the parallax makes use of the zenith distance directly instead of computing the Rsine altitude of the central ecliptic point and then deriving zenith distance of the central ecliptic point, as given by Brahmagupta. Dṛggati for Āryabhaṭa meant the zenith distance in the direction of ecliptic and Dṛkṣepa [zenith to the ecliptic, the shortest distance *ZV*, is perpendicular to the ecliptic and bisects the ecliptic at 90° behind the Prāg-Lagna, according to verse 21 of Goḷa], the zenith distance in the direction perpendicular to the ecliptic, thus deriving Dṛggatijyā $=\sqrt{(\text{Drgjyā}(zd)^2 - \text{Dṛkṣepa}^2)}$. Brahma-

Table 4. Solar eclipse–parallax correction by traditional method. Location: 10N51, 75E45

Time	Udaya	Madhya	Drksepa	Drg	Drggati	Parallax	Min	Brahmagupta
14:07	687.10	620.04	607.54	1708.32	1596.64	24.38	53	58
13:14	671.45	247.03	242.28	1020.57	991.40	15.14	33	35
12:41	667.23	22.01	21.59	583.11	582.71	8.90	19	20
12:22	666.84	102.19	100.25	358.19	343.87	5.25	11	12
12:11	667.32	171.83	168.56	270.38	211.40	3.23	7	9
12:04	667.91	215.12	211.03	253.03	139.61	2.13	5	8

Table 5. Planetary longitudes at 12 noon on AD 519 August 11

Graha	λ	β	Elongation	Remarks
Sun	139°05′45″	–		
Moon	139°04′15″	–00°07′	–0.025	New moon
Mars	289°09′02″	–06°11′	150.05	
Mercury	124°20′50″	01°08′	–14.75	28 August s. conjunction
Jupiter	98°24′27″	00°07′	–40.69	β is low: Node on 2 June
Venus	103°18′10″	–00°31′	–35.79	Node on 20 August
Saturn	289°58′49″	–00°35′	150.88	
Rāhu	137°50′	–	≈2°	
Apogee–Moon	146°21′	–	≈7°	

gupta, on the other hand, had configured the triangle with Dṛkṣepa as the base and Dṛgjyā as the hypotenuse. It is likely that the choice of the triangle by Āryabhaṭa is because of his method by use of more accurate zenith distance and altitude observable from a sea horizon. In the brief treatise of *Āryabhaṭīyam*, verses 28–30 of Goḷa pertain to observations against the horizon.

(e) Further, it may be noted that the parallax correction computed for the solar eclipse by the method of Āryabhaṭa gives quite accurate results.

(iii) An interesting inquiry may be the visibility of Venus, Jupiter and Mercury during the totality. Planetary longitudes for the date at 12 noon are given in Table 5.

Jupiter, Mercury and Venus were morning stars with elongation required as to be visible. But the position of Āryabhaṭa on the west coast was disadvantageous to watch them against the sea horizon. It is therefore possible that he decided to move a little south to Kanyākumāri, where both the rising planets and the luminaries setting after the eclipse could be observed. It may be noted here that the Siddhāntic tradition treats Kanyākumāri as falling in the Laṅkā–Ujjayinī meridian, even though its present longitude is off the Ujjayinī longitude by more than a degree or 9 Yojanas.

(iv) Āryabhaṭa's voyage down to the south in a boat/ship (naukā) may be at the source of the following description that is seen in *Āryabhaṭīyam*[10]:

अनुलोमगतिर्नौस्थः पश्यत्यचलं विलोमगं यद्वत्
अचलानि भानि तद्वत् समपश्चिमगानि लंकायां ।९।
उदयास्तमयनिमित्तं नित्यं प्रवहेण वायुना क्षिप्तः
लंकासमपश्चिमगो भपञ्जरः सग्रहो भ्रमति ।१०।

'Just as the objects on the shore have been felt to move in the backward direction while moving in a wind boat, the fixed stars appear to move from east to west while observing the sky on the prime meridian of Laṅkā. It appears as if the canopy of stars is moving west of Laṅkā, as if driven constantly by the pravaha wind to cause their rise and set.'

Āryabhaṭa refers to the experience of a voyage in the sea (nauka is boat in water; of course it can be disputed as Shukla translated the verse that he is referring to a voyage in some river), perhaps in a fast-moving wind-boat and witnessing the receding of objects on the shore while the sky keeps pace with the traveller. Apparent motion of objects on the shore like hills or beacons backwards while the sky and its lights keep pace with the travelling observer, may have conveyed him the impression that the earth is rotating and the starry sphere is stationary. Further, Kanyākumāri, where the eclipse was total, offered Āryabhaṭa the chance to observe both sunrise and sunset, and his genius could have easily understood that it is the water table that is revolving to make the sun rise and set. It may also be noted that the observations available to him were remarkable at Kanyākumāri – the morning sighting of the rise of Mercury two hours before sunrise, when Jupiter and Venus were at heights of 25° and 20° respectively, and then the eclipse at noon followed by sunset, all from the same place. Āryabhaṭa says; 'Udayāstamaya nimittam... Laṅkā samapaścimago bhapanjaraḥ sagraho bhramati'. This observation was possible only at Kanyākumari. These verses must be interpreted taking into consideration the sky observed by him above the east and west sea horizons at Kanyākumāri, to understand his adherence to the revolutionary concept of earth's rotation. It must be noted that questions like those asked by Lalla or Brahmagupta did not strike Āryabhaṭa as experience conveyed him that the earth was rotating along with the water and the atmosphere.

(v) Āryabhaṭa had Mercury, Jupiter and Venus positions relative to a solar eclipse happening on the meridian and he also had apogee of moon, the eclipse being annular. Therefore, modification of the bhagaṇas and the accuracy that we see in Āryabhaṭa may be ascribed to the observation of the solar eclipse and the sky at Kanyākumāri on AD 519 August 11.

Two partial lunar eclipses

AD 519 marked by the solar eclipse on the Laṅkā–Ujjayinī meridian is also significant because of (i) a total solar eclipse on 15 February, totality visible at 10N51, 75E45 and (ii) the two partial lunar eclipses that sandwiched the annular solar eclipse of 11 August:

(a) 27 July at 22:28 Ujjayinī mean time; sun and moon were respectively at 125:00 and 305:00.
(b) 26 August at 06:05 Ujjayinī mean time; sun and moon were respectively at 153:28 and 333:28.

In both lunar eclipses, the moon was near the perigee and during these lunations there have been planetary conjunctions of the moon, which were required to fix their positions and to have the necessary modifications to the revolution numbers. The second last verse of Gola 48 with which the astronomical contents of the Āryabhaṭīya have been concluded[10].

क्षितिरवियोगात् दिनकृत् रवीन्दुयोगात् प्रसाधितश्चेन्दुः।
शशिताराग्रहयोगात् तथैव ताराग्रहाः सर्वे ।४८।

'Sun is computed from the earth–sun conjunctions, Moon is computed from its

Table 6. Planetary phenomena described in verse 48 of Goḷapāda

Planetary conjunction	Date	
Lunar eclipse	July 27	Perigee close
Moon–Venus	AD 519 August 8	Visible in the morning
Moon–Jupiter	AD 519 August 8	Visible in the morning
Moon–Mercury	AD 519 August 10	Visible in the morning
Moon–Sun	AD 519 August 11	Eclipse at noon
Moon–Mars	AD 519 August 23	Visible at night overhead
Moon–Saturn	AD 519 August 23	Visible at night overhead
Lunar eclipse	August 26	Also perigee

conjunctions with the sun and the star-like planets are computed by observing their conjunctions with the moon'.

A good illustration of the above verse could be seen at the above date of the solar eclipse of AD 519 August 11 and in the sandwiching lunations as given in Table 6.

All the phenomena that Āryabhaṭa mentioned in the concluding verse of *Āryabhaṭīyam* without exception could be observed on either side of the solar eclipse that happened on the meridian of Ujjayinī.

Ancient observatory possible at Kanyākumāri

At the outset it may seem preposterous to claim that an ancient observatory may have been there at Kanyākumāri. But the following aspects suggest the possibility of astronomical knowledge in what had been South Travancore before the linguistic reorganization of the states.

(a) Kanyākumāri, Nagarkovil and Thiruvananthapuram (Anantapuram) are place names that owe their origin to astronomical knowledge about the zodiacal signs, Kanyā (Virgo) and Simha (Leo). 'Nāgar' of Nagarkovil and 'Ananta' of Anantapuram owe their origin to the constellation Draco, in which the pole of the ecliptic is situated. Pole of the ecliptic has the name Viṣṇu-nābhi in mythology and is the source of the legend of Dhṛuva performing penance to obtain a boon from Viṣṇu.

(b) Near Nagarkovil, the ancient capital of Venādu had the name Padmanābhapuram, in honour of Viṣṇu, the ecliptic north pole.

(c) The prehistoric temple at Tiruppatīśvaram has Viṣṇu surrounded by the Seven Sages or Saptarṣis – depiction of the daily round of the Sages around the pole of the ecliptic visible in Kanyākumāri. Major city of central Kerala 'Erṇākulam' is known to be 'Ṛṣināgakulam' meaning, 'home of the Sages and the snake', obviously the reference is to constellations Seven Sages (Ṣaptarṣis) and Draco.

(d) Also, ancient homes in Thiruvananthapuram and around, viz. the seven blocks (ezhu-kettu) had a layout derived from the relative stellar positions of the Seven Sages in the sky. These homes had the ancient name, Naññol meaning the Plough or Regulus, the star Maghā of Leo.

(e) Maghā nakṣatra of the solar month of Kanyā is celebrated in the area as the birth star of rice or paddy; the virgins taking birth in Maghā nakṣatra is extolled in old folk sayings as harbinger of great prosperity.

(f) In colloquial Malayalam, the name Nārāyāṇa means water snake because of the connection of Nārāyaṇa to the ecliptic North Pole situated in Draco. Also, the name Nňňeli means both a virgin and a frog.

(g) Kerala has two calendar norms, where the new year begins with the solar month of Leo and Virgo, and the same tradition of solar calendar prevails in areas of South Tamil Nadu close to Travancore.

(h) Observational advantage of the east and west sea horizons available at Kanyākumāri could have been an attraction to ancient astronomers.

Conclusion

It is apparent from the above that Āryabhaṭa who heralded the beginning of the mature phase of Indian astronomy in the 6th century CE, had his astronomical observations in the southern state of Kerala. Precisely his location was 10N51, 75E45, the confluence of the river Niḷa in the sea and the point where the west coast of the subcontinent intercepted the prime meridian of Ujjayinī.

In continuation with the identification of the place of observation, examination of the veracity of the legends concerning his eclipse observations from the sea leads one to the annular solar eclipse of AD 519 August 11, the totality of which occurred on the meridian of Laňkā and 2° south of Āryabhaṭa's place, modern Ponnāni.

Āryabhaṭa's modification of the solar year length, drastic changes to the revolution numbers of the Moon's node and apogee, parallax correction, and observation as given in verse 48 of Goḷapāda, all meet with satisfactory explanation about the planetary phenomenon observable from Kanyākumāri around the date of the above solar eclipse.

The astronomical phenomenon of AD 519 August, falling close to the epoch Kali 3623 of Āryabhaṭa, adds credence to the legends regarding his sea voyage and eclipse observation from the sea. The planetary phenomena that occurred during the two lunations that sandwiched the solar eclipse find expression in the verse 48 of Goḷapāda, where the phenomenal basis of Āryabhaṭa's observations and working out of the treatise has been summarized.

Āryabhaṭa's adherence to the theory of the earth's rotation and apparent revolution of the starry canopy may have their genesis from the experience of apparent motion of the shore during his sea voyage along the coastline.

1. Hari, C. S., Critical evidence to fix the place of Āryabhaṭa-I. *Curr. Sci.*, 2007 (accepted); Intricacy of certain verses of Āryabhaṭiya and Jain tradition – Identification of Aśmaka as Sravaṇabelgola – comravattan. Jain Country. 2007, *Curr. Sci.* (submitted).
2. Kochhar, R. K.; http://nistads.res.in/ppl/rkk/papers/vistas in astronomy.pdf
3. http://www.namboothiri.com/articles/contributions.htm
4. Jean Meeus and Willmann-Bell, Computed as per the polynomial expressions available in *Astronomical Algorithms*, Richmond, Virginia, 1991.
5. Shukla, K. S., *Āryabhaṭīyam, verse 13 of Goḷa*, INSA, New Delhi, 1976, p. 123.
6. Sastry, T. S. K. and Sarma, K. V., *Pancasiddhāntikā*, PPST Foundation, Adyar, Chennai, 1995.
7. Sarasvatī, Satyaprakash Swami, *A Critical Study of Brahmagupta and his Works*, Govindram Hasanand, Delhi, 1986, p. 49.
8. Shukla, K. S., *Mahabhaskariya*, Lucknow University, 1960, p. 65.
9. Sharma, S. D., *Eclipses, Parallax and Precession of Equinoxes*, INSA, New Delhi, 1985, pp. 200–201.
10. Shukla, Kripa Shankar and Sharma, K. V., *Āryabhaṭīyam*, Indian National Science Academy, New Delhi, 1976, p. 119; 162.

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