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EPOCH OF *ROMAKASIDDHĀNTA*

K. CHANDRA HARI*

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The paper attempts to identify the original epoch of *Romakasiddhānta* complied by Varāhamihira in his *Pañcasiddhāntikā*. Based on the algorithm for Rāhu and also supported by other features of mean sun, and moon algorithms, the epoch of the original *Romakasiddhānta* is shown to be Sunday, 19 March 52 AD, sunset at Yavanapura (Alexandria). Romaka year beginning with Monday sunset as described in verse 8 of *Pañcasiddhāntikā* is shown to be irreconcilable with the epoch of Śaka 427 and has been shown to be a vestige of the original epoch where in on Monday 20 March 52 AD, the crescent was visible and thus the New year began as per the Hellenistic-Babylonian norms.

Key words: *Romakasiddhānta, Pañcasiddhāntikā, Varāhamihira, Yavanapura, Śaka* 427, 52 *AD*.

INTRODUCTION

The *Romakasiddhānta* available in the Varāhamihira's compilation of the *Pañcasiddhāntikās* is considered to be very ancient and a part of the Greek astronomy transmitted to India. As noted by Sharma[1] the use of sunset epoch, tropical year, relation to the 19 year cycle, reference to Yavanapura etc are suggestive of the foreign origin of the treatise and the epoch adopted in the compiled version of the text is sunset of Alexandria (31N13, 29N55) on 21st March 505 AD. According to Sen[2], in all probability, it was *Lāṭadeva* who recasted the original to make it conform to a later epoch namely Śaka 427 which Varāha adopted. A study of Romaka is available in *Pañcasiddhāntikā* critically edited with translation and notes by TSK Sastry and KV Sarma, but all these works are silent about the original date of the *Romakasiddhānta*. As indicated by Varāhamihira in verse 3 of the first chapter '*Karaṇavatāraḥ*', the Romaka and Pauliśa had their commentaries by Lāṭadeva, the pupil of Āryabhaṭa who pre-

* B-204, Parth Avenue, Near ONGC, Ahmedabad - 5

ceded him by a generation as may be understood from Varāhamihira's references to Āryabhaṭa and Lāṭa in his work. It's unlikely that Lāṭa and Varāhamihira were contemporaries and discussion in this regard may be seen in the work of Dikshit where it is said that Lāṭa lived before Varāhamihira.[3] Dikshit[4] has further commented upon the possible period of origin of the *Romakasiddhānta* as compiled after the times of Hipparchus (150 BC) and before Ptolemy II (150 AD) in view of the use of Hipparchian solar year of 365.246667 days. A discussion on the different versions of *Romaka/Romakasiddhānta* is also available in the work of Dikshit. The *kṣepakas* as per *Pañcasiddhāntikā* are:

Sun= 359°34', Moon = 359°19', Moon's *Kendra* =72°20', Rāhu = 235°49' - according to Dikshit true for the moment of sunset at Ujjayinī on Sunday, 14th *Caitra Kṛṣṇa*, 20 March 505 AD[5]. Solar aphelion as per the treatise is 75° - in error by nearly 3° and different from the values of other Siddhāntas - an indication of the ancient origin of the treatise and its recasting for later times.

Choice of Śaka 427 or 505 AD for the Recast of *Romaka*

The factors that guided the choice of Śaka 427 or Kali 3606 elapsed for the recasting of the *Romakasiddhānta* remains unknown despite modern studies of the last 200 years. Present paper is an effort to have a look at the factors that possibly guided Lāṭa or the unknown astronomer for choosing Śaka 427 as the epoch of *Romakasiddhānta*. In making this investigation we need to have a look at the computational frame of *Romakasiddhānta* as compiled by Varāhamihira in the sixth century AD.

(a) Epoch of the work

Epoch of the work according to verse 8 of chapter I of *Pañcasiddhāntikā* is Śaka 427 elapsed, sunset at Yavanapura as shown by Sastry and Sarma[6]. Kali 3606 and Śaka 427 elpased at the *Kalyādi ahargaṇa* of 1317123.053 which nearly coincide[7] with Monday, 21st March 505 AD, 06:00 LMT of Ujjayinī. Mean longitudes and the true positions for the epoch according to modern algorithms are:

Monday, 21st March 505 AD, 06:00 LMT, Ujjayinī			Romaka Mean values
Planets	Mean λ	True λ	Mean λ
Sun	359° 59'	01°58'	359°34'
Moon	359°14'	354°54'	356°12'
Rāhu	235°57'	234°01'	235°49'
Apogee-Moon	99°37'	101°16'	≅ 72°20'

It's evident from the above that the Indian Siddhāntic epoch of the works like *Sūryasiddhānta* based on *Yugādi* computation as adopted by Varāhamihira was Monday, 21 st March 505 AD, 06:00 LMT, Ujjayinī. Whereas the Romaka epoch adopted probably from the commentary of Lāṭadeva was different viz., sunset of Sunday and this difference between the Indian system and the Romaka as well as the difference of modern values and the *kṣepakas* can be understood from the algorithms of mean sun and moon.

(b) Rationale of the computation of mean sun and mean moon

1. Verse 1 of chapter 8 gives the computation of mean Sun as: (Days x 150 - 65)/54787 which means that the sun completed its revolution (65/150) = 0.4333 days = 26 *nāḍīkās* after the epoch which is very true as the mean sun of Romaka for the epoch's only 359°34'.

2. Likewise the algorithm for mean moon leads us to the inference that the moon completed its revolution (10984/38100) = 0.28829 days = 17.3 *nāḍīkās* after the epoch. This shows that Sunday, 20 March 505 AD, 16:14 UT sunset (18:14 LMT) at Yavanapura [1905588.17618] is the epoch[8] for *Romakasiddhānta*:

Planet	Modern mean λ	*Romaka*	δλ of *Romaka* from 360°	Time to cover δλ of Romaka	Time to cover Modern δλ
Sun	359°38'	359°34'	0°26'	26 *nāḍikās*	22 *nāḍikās*
Moon	354 °27'	356°12'	3°18'	17.3 *nāḍikās*	25.3 *nāḍikās*
Rahu	235°58'	235°49'			

Moon is inaccurate by nearly two degrees when compared with modern mean λ. New moon occurred at JD (UT) =1905589119659, Monday 21 March 505 AD 14:52 UT with the sun and moon at true λ =02°32'. .

It is important to note here that the solar year of *Romaka* was 365.24666 days while of Varāhamihira and the Indian school was 365.25875 days. We can see in *Pañcasiddhāntikā* the reconciliation of the Siddhāntic and *Romaka* year lengths at the Siddhāntic epoch of Śaka 427(elapsed) with a difference of just 0.5 days. Original epoch of *Romaka* must be bridgeable to Śaka 427(elapsed) by a new moon similarly placed relative to the zero point and the difference in λ accountable by the precession arc and the difference in the lengths of the solar years.

(c) Algorithm for Mean Rāhu leads to the Original *Romaka* Epoch

Mean Rāhu = 360° - [(days x 24) + 56266]/163111, which implies that at (epoch - 56266/24) days the Rāhu was at 360° and in 163111 days Rāhu completes 24 revolutions.[9]

Epoch – 56266/24 = 1903243.759 (Wednesday, 14-10-498 AD) days for which modern mean Rāhu = 0°07' (true λ = 1 °42'). According to *Romaka*, Rāhu is at zero before 24 revolutions in 163111 days – that is, JD = 1740132.759, 23 March 52 AD. On looking for an epoch, new moon coinciding zero as in the case of Śaka 427, around the date, we find:

New Moon: 1740128.98139 UT, 19 March 52 AD, 11:23, / =357°17', Sunday 13:33 LMT at Yavanapura. This new moon is spaced (-)165460.138 days = (-)5603 lunation from the new moon epoch of *Pañcasiddhāntikā*. Crescent visibility was on 1740130.1743056, Monday, 20 March, 52 AD, 1811 LMT, sunset at Yavanapura. Sunset epoch we see in *Pañcasiddhāntikā* on Sunday, 20th March 505 AD is meaningless as the crescent is not visible and therefore does not qualify to be an epoch as per the Babylonian/ Egyptian canon.

Planet	Sunday 13:33 LMT		Sunday sunset, 1811 LMT		Monday sunset	
	Mean λ	True λ	Mean λ	True λ	Mean λ	True λ
Sun	355°16'	357°17'	355°27'	357°28'	356°26'	358°27'
Moon	358°17'	357°17'	00°49'	00°10'	14°00'	15°13'
Rāhu	357°58'	≅ 357°51'	357°58'	≅ 357°51'	357°54'	≅ 357°51'

Apparently the new moon and Rāhu did not coincide the zero - were nearly 2°.5 west of the vernal equinox. But according to the Babylonian tradition of sidereal zodiac, sun, moon and Rāhu very nearly coincided the sidereal zero point, which in 52 AD was 2.5 degree west of the vernal point. Combined with the fact that the recast *Romakasiddhānta* gives complete revolutions to Rāhu at this epoch (which falls between the times of Hipparchus and Ptolemy), it is likely that the original *Romakasiddhānta* was based on the sidereal zodiac that prevailed in Alexandria in the pre-Ptolemy period.[10]

Algorithm of Rāhu finds no other explanation. Further it may be noted that the difference between the *Romaka* and Siddhāntic solar year was 0.01209 days and in 453 years the difference amounted to 5.476 days, corresponding to the 5 degrees that separated the new moons under reference over the ecliptic. In other words, a siddhānta having the parameters of *Romaka* originating in 52 AD could have been adopted in Siddhāntic astronomy only at the epoch of Śaka 427. Epoch of Śaka 427 elapsed in fact is a vestige of the original epoch of Romaka falling in 52 AD.

(d) Evidence of the Solar Aphelion

The *Romaka* puts the aphelion at 75°, which is unique among the Siddhā ntas. In 52 AD, Sun "was at aphelion on June 3, JD (UT) = 1740204.856285, λ = 70°08' which was 75° east of the mean sun (355°16') that marked the epochal new moon of *Romakasiddhānta*. Thus the solar aphelion of the treatise provides additional support to the 52 AD epoch.

(e) Solar Eclipse of 19 March 52 AD at Alexandria

Above epoch was also marked by a solar eclipse visible at Alexandria - Beginning: 14:07, Middle: 15:13, End: 16: 14 and of magnitude:0.62. So the epoch was definitely of observational significance to Alexandrian astronomers.

(f) Parameters of Original *Romakasiddhānta*

- Important observations are: New moon at JD (UT) =1740128.08139, 19-03-52 AD, 13:33 ZT, Sun = 355.261, Moon = 358.2755
- Sunday sunset at Yavanapura: 1740129.17430556 UT, 19 March 52 AD, 1811 ZT, Sun = 355.451, Moon = 0.8174
- Monday sunset at Yavanapura: JD (UT)=1740130.1743056, 20th March 52 AD, 18:11 ZT, Sun = 356.4365, Moon = 14°.0

Taking Sunday sunset at Yavanapura as marking the complete revolutions of sun and moon, we get 165459 days between the two epochs and this interval must have played a critical role in deciding the multipliers and divisors of *Karaṇa*.

- It is divisible by 7 and therefore the weekday rules shall be the same.

- – 165459/365.25875 = 3°.167 is obtained as the arc covered by the Siddhāntic sun while the Romaka sun is 357.7724 and the difference is 5°.395. Romaka sun is faster and the above difference when added to mean sun of the epoch gives 360.846, nearly 1° in surplus - arising out of the extra-long sidereal years of the Siddhāntas (365.25875) which contributes an error of (-) 1° in 450 years as the Varāhamihira sun was slower than the true sidereal sun. Computing mean sun with the parameters of *Karaṇa* yields for 165459 days, the mean sun as 357.3453 + 0.43 = 357.77 where 0.43 is the *kṣepaka* that completes the revolution.
- Mean moon computed for (-) 165459 days will be 4°.317, which is nearly the same as the *kṣepaka* for Sunday sunset as per *Pañcasiddhāntikā* to complete the revolution.
- Mean Rāhu computed for (-)165459 days is 0°.189 = 0°11' which is the same as that of 14-10-498 AD, where the mean Rāhu is zero as per *Pañcasiddhāntikā* as explained earlier.

It is well evident from the above that the original *Romakasiddhānta* had its genesis 165459 days before the Varāhamihira epoch of Śaka 427, i.e. in 52 AD at Yavanapura.

Reconciling the contradiction apparent in *Pañcasiddhāntikā*

Pañcasiddhāntikā verse 8 of chapter I reads as[11]:

saptāśviveda (427) saṅkyam śakakālamapāsya caitraśuklādau /
ardhāstamite bhānou yavanapure somadivasādyaḥ /8/

"Deduct 427 from the śaka year beginning with Caitraśuklapakṣa, the epoch is obtained as sunset at Yavanapura on Monday..."

It is amply clear from the earlier discussion that the epoch as could be gleaned from the *kṣepaka* of *Pañcasiddhāntikā* can only be Sunday and not Monday. Monday (21 March 505 AD) sunset at Yavanapura has nothing to do with the *Romakasiddhānta* of the *Pañcasiddhāntikā* as is evident from the computation. Mean sun had been zero at 01 :11 UT and sunset of Yavanapura was after 15 hours (UT: 1905589.1746), almost coinciding with the true new moon at 14:52 UT (UT: 1905589.119659) and thus the crescent invisible and the year could not have begun. Therefore the sunset of Yavanapura on Monday of which we meet the reference in *Pañcasiddhāntikā* is in fact a reproduction of the original year beginning of *Romaka* as per Babylonian calendar norm of crescent visibility on Monday, 20 March 52 AD.

Conclusion

On the basis of the computational features of *Romakasiddhānta* availabe in *Pañcasiddhāntikā*, the original epoch of *Romakasiddhānta* is identified as Sunday sunset at Yavanapura on 19 March 52 AD.

Longitudes of luminaries and Rāhu for the above epoch (357°28') suggest that the original *Romakasiddhānta* was based on the Babylonian sidereal zodiac and zero point having a three-degree norm for the vernal equinox. True sun of the epoch suggests an *ayanāṃśa* of 2.5 degree to be added and therefore the vernal point coincided Romaka zero point in 23 AD.

Romakasiddhānta of *Pañcasiddhāntikā* thus point towards the loss of the rationale of zero point and adoption of vernal equinox as zero in the efforts of ancient astronomers to adopt the treatise for a later eopch in the Ptolemaic era.

Epoch of *Romaka* as identified here is the only evidence of a Siddhānta that has come to light in respect of the use of sidereal zodiac in ancient times.

References

1. S D Sharma, "Post Vedic Astronomy", *History of Astronomy in India*, eds S N Sen, K S Shukla, INSA, New Delhi (1985), p.136.
2. Ibid, p.80.
3. S B Dikshit, *History of Indian Astronomy*, Publications Division, Govt of India, New Delhi, p.35.
4. Ibid, p.12.
5. Ibid, p. 12.
6. T S K Sastry and K V Sarma, *Pañcasiddhāntikā*, PPST Foundation, Chennai-20, (1993), p.7.
7. As per the *audayika* system the difference is only 3.18 *nāḍikās* , which is ignored, in the present discussion.

8. True λs for sun and moon are $1°37'$ and $350°\ 10'$ for the Romaka epoch of Sunday sunset at Yavanapura.

9. T S K Sastry and K V Sarma, *Pañcasiddhāntikā*, PPST Foundation, Chennai-20, (1993), p.186.

10. The first observation made by Ptolemy which is dateable exactly was on 26 March 127 while the last was on 2 February 141.

11. T S K Sastry and K V Sarma, *Pañcasiddhāntikā*, PPST Foundation, Chennai-20, (1993), p.6.