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A HYPOTHETICAL *ROMAKASIDDHĀNTA* CALENDAR

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Abstract: The *Romakasiddhānta* is a quite special Hindu luni-solar canon being the only one using Metonic intercalation and implementing a tropical solar year. As the name suggests it has a Hellenistic origin. The known facts about the canon are scanty but in spite of this it is possible to draw some conclusions from them. A hypothetical calendar based on its known characteristics is investigated below.

Keywords: *Romakasiddhānta*, calendar, lunisolar, intercalation

1 INTRODUCTION

The *Romakasiddhānta* calendar (Neugebauer, I: 29, II.8, Sastry, 7) was one of the five astronomical canons popular in India in the fifth century CE mentioned in Varahamihira's *Pañchasiddhāntika* (van der Waerden, 1988). It represents a lunisolar calendar where the lunar calendar is synchronized with the solar year by intercalating months and days. It uses the relation that 703 lunar days or *tithis*, a *tithi* being exactly 1/30th of a synodic month, correspond to 692 solar days. This relation is also used in the Thai and Burmese traditional calendars in Southeast Asia. The calendar uses a Metonic intercalation scheme of lunar months; each 19-year cycle having seven years with an intercalary thirteenth lunar month. This kind of intercalation generates an average year length that is not sidereal as for the other Hindu canons but instead results in a tropical year. In fact, a 19-year cycle will contain 19·12 + 7 = 235 lunar months or 235·30 = 7050 *tithis*. This is equal to 7050·692/703 = 6939.687055 solar days giving a mean solar year length of 6939.687055 / 19 = 365.246687 days, almost exactly equal to Hipparchus' tropical year 365 + ¼ – 1/300 days. The epoch of the *Romakasiddhānta* canon is 21 March 505 CE, Śaka 427 (van der Waerden).

2 THE CALCULATIONS

The *Romakasiddānta* has a rule for calculating the number of elapsed *tithis* since the epoch:

(1) Multiply the elapsed number of Śaka years diminished by 427, *y*, with 12 to convert them to lunar months.
(2) Add the number of elapsed months, *m*, of the year to get the total number m_0 of normal elapsed months: $m_0 = y \cdot 12 + m$.
(3) Find the number of intercalary months, m_1, by $m_1 = m_0 \cdot 7 / (12 \cdot 19)$. This implements the rule of seven intercalary months in each 19-year cycle.
(4) The total number of elapsed months is then $m_0 + m_1$.
(5) Convert the total number of lunar months to elapsed *tithis* by multiplying by 30.
(6) Add the number of elapse *tithis*, *t*, of the month to get the total number of elapsed *tithis*, *T*.
(7) In mathematical language the complete rule is:

$$T = ((y \cdot 12+m) + (y \cdot 12+m) \cdot 7 / 228) \cdot 30 + t = T(y, m, t). \quad (1)$$

The canon also gives a formula for converting elapsed *tithis* to elapsed solar days, the *ahargana*, *H*, by

$$H = T - (T \cdot 11 + 514) / 703 = H(y, m, t). \quad (2)$$

The number 514 is an era constant, specific for the *Romakasiddhānta*. The first term of the formula increases the *ahargana* in complete synchronisation with the *tithis*. The second term takes into account that a *tithi* is 692/703 of a solar day and that sometimes a *tithi* will not be in force at the sunrise of a solar day and will end before sunrise of the next day and will then be suppressed. This occurs whenever the second term increases by one unit or on average every 703/11 ≈ 63.91 *tithi* or 62.91 solar day or very nearly every ninth week. There will then be two *tithis* with the same *ahargana*.

Using formula (2) we can now calculate the length in solar days of a given year, *y*, by the difference

$$H(y + 1, 0, 0) - H(y, 0, 0). \quad (3)$$

For a given year, *y*, we can calculate the length of a given month, *m*, by the difference

$$H(y, m + 1, 0) - H(y, m, 0). \quad (4)$$

Also, the condition that in a given month, *m*, in a given year, *y*, there will be two *tithis* with the same *ahargana* is

$$H(y, m, t + 1) = H(y, m, t). \quad (5)$$

3 THE CALENDAR

Using the above relations (1)–(4), Table 1 shows the generated number of days in each month and the length of the year for the first two 19-year cycles in the calendar. The cycle year is the year modulus 19.

It is possible to draw some general conclusions:

(1) There are four kinds of years:
(a) Normal years with 354 days. These years will have a sequence of months with al-

ternating 29 and 30 days.
(b) Extended years with 355 days with an intercalary day. These years always have two 30-day months in sequence and always start and end with a 30-day month.
(c) Short intercalary years with 383 days. All these years are flanked by 355-day years. Years with 383 days always start and end with a 29-day month and have a long month with 59 days.
(d) Intercalary years with 384 days. Adjacent to some of these years there is one 355-day.

(2) The year pattern for the intercalary days is not very evident, it repeats only after 19·703 = 13357 years.

(3) The seven years in the 19-year cycle with number, 2, 5, 8, 10, 13, 16, and 18 have an intercalary month. This shows up in the table as a long month with 59 or 60 days, marked in red.

(4) The locations of the long month in the intercalary years follow a fixed repeating cycle being month 9, 6, 2, 11, 7, 4, and 12 for cycle years 2, 5, 8, 10, 13, 16, and 18 respectively.

(5) There are four patterns of days with months preceding and following a long month: 29 59 30, 30 59 29, 29 60 29, and 30 59 30. These patterns occur in 41%, 41%, 6%, and 12% of the cases respectively.

Table 1: Calendar years, months, and days.

Year	Cycle Year	Month												Year Length
		1	2	3	4	5	6	7	8	9	10	11	12	
0	0	29	30	29	30	29	30	29	30	30	29	30	29	354
1	1	30	29	30	29	30	29	30	29	30	29	30	30	355
2	2	29	30	29	30	29	30	29	30	59	29	30	29	383
3	3	30	29	30	30	29	30	29	30	29	30	29	30	355
4	4	29	30	29	30	29	30	29	30	30	29	30	29	354
5	5	30	29	30	29	30	59	29	30	29	30	30	29	384
6	6	30	29	30	29	30	29	30	29	30	29	30	29	354
7	7	30	29	30	30	29	30	29	30	29	30	29	30	355
8	8	29	59	30	29	30	29	30	30	29	30	29	30	384
9	9	29	30	29	30	29	30	29	30	29	30	29	30	354
10	10	30	29	30	29	30	29	30	29	30	29	59	30	384
11	11	29	30	30	29	30	29	30	29	30	29	30	29	354
12	12	30	29	30	29	30	29	30	30	29	30	29	30	355
13	13	29	30	29	30	29	30	59	29	30	29	30	30	384
14	14	29	30	29	30	29	30	29	30	29	30	29	30	354
15	15	29	30	30	29	30	29	30	29	30	29	30	29	354
16	16	30	29	30	59	29	30	30	29	30	29	30	29	384
17	17	30	29	30	29	30	29	30	29	30	29	30	30	355
18	18	29	30	29	30	29	30	29	30	29	30	29	59	383
19	0	30	30	29	30	29	30	29	30	29	30	29	30	355
20	1	29	30	29	30	29	30	30	29	30	29	30	29	354
21	2	30	29	30	29	30	29	30	29	59	30	30	29	384
22	3	30	29	30	29	30	29	30	29	30	29	30	29	354
23	4	30	30	29	30	29	30	29	30	29	30	29	30	355
24	5	29	30	29	30	29	60	29	30	29	30	29	30	384
25	6	29	30	29	30	29	30	29	30	29	30	30	29	354
26	7	30	29	30	29	30	29	30	29	30	29	30	29	354
27	8	30	59	30	29	30	29	30	29	30	29	30	29	384
28	9	30	29	30	29	30	30	29	30	29	30	29	30	355
29	10	29	30	29	30	29	30	29	30	29	30	59	30	384
30	11	29	30	29	30	29	30	29	30	29	30	29	30	354
31	12	30	29	30	29	30	29	30	29	30	29	30	29	354
32	13	30	29	30	29	30	30	59	29	30	29	30	29	384
33	14	30	29	30	29	30	29	30	29	30	30	29	30	355
34	15	29	30	29	30	29	30	29	30	29	30	29	30	354
35	16	30	29	30	59	29	30	29	30	29	30	29	30	384
36	17	29	30	29	30	30	29	30	29	30	29	30	29	354
37	18	30	29	30	29	30	29	30	29	30	30	29	59	384

In the first pattern the suppressed *tithi* will always occur in the second half of the 59 days of the long month which is split into two months according to 29 59 30 → 29 30 29 30. In the second pattern the suppressed *tithi* always occurs in the first half of the long month and the split is accordingly 30 59 29 → 30 29 30 29. In the third pattern there is no suppressed *tithi* in the long month and consequently it is split in two equal parts, each with 30 days. In the last pattern the way to split the long month will be determined by the half in which the suppressed *tithi* occurs. In general, the split prevents having two 29-day months days following each other.

(6) Years with 384 days either start with a 29-day month and end with a 30-day month or vice versa. Years with a long month of 59 days always have two consecutive 30-day months or have the long month flanked by two 30-day months, for those years with a long month of 60 days these two consecutive months arise from the split long month, 60 → 30 + 30.

4 CONCLUDING REMARKS

This calendar, generated by the rules given in the *Romakasiddhānta*, has similarities to the common Hindu calendars in that it tries to synchronise the length of the months with the mean Moon using a system of suppressed *tithis* and days inserted when needed. It also synchronises the lunar year with the Sun with intercalary months, but in contrast with the Hindu calendars it uses a tropical solar year and not a sidereal year. The calculations required to set up the calendar are quite simple and only require integer arithmetic. It would be quite accurate relative to the true tropical year, the error being only about one day in 220 years. The resulting calendar has some similarities with the original Burmese Arakanese and Makaranta calendars in using a Metonic intercalation scheme. With small changes in the day intercalation to achieve year lengths of 354, 384, and 385 days it would be even more similar and raises the question of the influence of this canon on the calendars in South-east Asia.

5 REFERENCES

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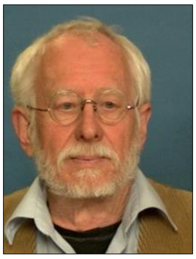

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