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THE CALENDARS OF SOUTHEAST ASIA. 1: INTRODUCTION

Lars Gislén
Dala 7163, 24297 Hörby, Sweden.
Email: larsg@vasterstad.se

and

J.C. Eade
49 Foveaux St., Ainslie, ACT 2602, Australia.
Email: jceade@gmail.com

Abstract: In this chapter we examine calendars in general and also give a condensed political history of the region. We then discuss the influences of Indian, Chinese, and Islamic astronomy in Southeast Asia. In subsequent papers in this series we will examine in detail the astronomy and calendars found in Burma (Myanmar), Thailand, Laos, Cambodia, Vietnam, Malaysia and Indonesia, and the inscriptions, manuscripts and horoscopes associated with them.

We have already written about most of these regions previously, but in this series of papers we will update our earlier publications and synthesize them in order to present a detailed coherent picture of the calendars of SE Asia.

Keywords: Calendars, Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia, Indonesia, India, China, Islam

> "The investigation of the transmission of mathematics and astronomy is one of the most powerful tools for the establishment of relations between different civilizations". (Neugebauer, 1952: 1).

1 WHAT IS A CALENDAR?

A calendar[1] is a device for measuring and organising time and is an integral part of everyday society and is often closely connected with religion and have been used from the earliest times to regulate agricultural and economic activities. The sky with its constellations of stars can serve as an anchor for a calendar. Many cultures in Southeast Asia and elsewhere used the heliacal rise of the Pleiades or of the constellation of Orion for this purpose, marking the beginning of the harvest year. The spring or autumn equinoxes or the summer or winter solstices have also been used in the same way, an example is the Indonesian *mangsa* calendar; and the Egyptians used the heliacal rising of Sirius. Again, the early Roman calendar started the year close to the spring equinox in March and we can still see in the names of the Western months, September, October, November and December that they were once months seven to ten in a lunar calendar starting the count with March. Calendars have with few exceptions a strong relation to astronomy.

The solar day is the natural unit of time for most calendars. One of the ideas of a calendar idea is to attach a unique identifying tag to each day, its date, as when specifying the year, month and day, although there are several other options to achieve the same goal—for example by adding redundant information like specifying the weekday.

In some cases, also the time of the day is specified as is done with the Indian *lagna* or rising sign of the zodiac. Solar days are structured in larger units or cycles like weeks, months and years. People of all ages have used different natural or artificial periodic cycles in order to construct their calendars. An early natural cycle, certainly used since the dawn of humanity, is the cycle of the phases of the Moon. This gives a system of easily manageable time blocks, the full phase cycle of 29 or 30 days, the synodic month and the time between the different lunar phases, about seven days that may be the origin of the 7-day week that is very ancient. The Islamic calendar is one such pure lunar calendar, the start of each lunar month being determined by the first visual observation of the New Moon crescent in the evening, with the year having 12 such lunar months where there is little or no need of any numerical calculation. Examples of more artificial calendar cycles with little connection with natural events are the 260-day *tzolkin* used by the Mayans based on subcycles of 13 and 20, and the 210-day Balinese *Pawukon* calendar.

Calendars can be divided into two types: astronomical calendars based on real events in the sky like the original Islamic calendar mentioned above and the Chinese calendar; and arithmetic calendars based on cycles and/or arithmetical rules although with relations to the celestial sky. Most of the calendars in Southeast Asia are of the latter type.

Different calendar schemes begin the solar day at different times. India has two canonical variants that are relevant here, the *Sūryasiddhānta* canon, in which the astronomical day begins at midnight, the *ārdharātrika* system, and the *Aryabhāta* canon where it begins at sunrise, the *audayika* system. The civil day in the calendars of Southeast Asia normally begins at sunrise but the astronomical day begins at midnight. This in some cases creates an ambiguity in determining the day number and the name of the weekday, there can be different weekdays and day numbers if the time of the day is located between midnight and sunrise, depending on whether the astronomical or civil convention is used. In the Islamic calendar the civil day always begins at sunset.

Once agriculture became common, there was a need for calendars that were correlated with the seasons, i.e. with the Sun. Such a calendar is the Egyptian calendar having a year of 12 months of 30 days each and five extra days, in total 365 days, a rather crude approximation to the true solar year but later improved with an extra leap day. The Western Julian and Gregorian calendars are examples of solar calendars that follow the seasons quite accurately by using leap days although an implicit lunar calendar is still used to determine Easter and the ecclesial year. A happy compromise can be made by combining the solar and lunar calendar into a luni-solar calendar.

In luni-solar calendars there are four sequences of time that need to be synchronised: the progress of the Sun, the solar calendar, the lunar calendar, and the progress of the Moon. As a solar year is slightly more than 365 days, and a solar calendar contains an integral number of days, there is a need to insert leap days, resulting in a solar calendar year with 365 or 366 days. The Julian calendar, in use before CE 1582 (Common Era), intercalates a leap day every four years, in every year divisible by four, and approximates the solar year with an average of 365.25 days. The Gregorian calendar fine-tunes this by skipping the leap day every century year where the century is not divisible by four and has a solar year with 365.2425 days, a rather good approximation of the real tropical solar year with 365.2422 days.[2] The Indian luni-solar calendars in Southeast Asia use a sidereal solar year with 365.25875 days or in the later Burmese luni-solar calendar based on the modern *Sūryasiddhānta* with 365.25875648 days. Such solar years will be about 11 days longer than a lunar year with 12 synodic months with a mean length of about 29.5 days and giving a total of about 354 days. In order to synchronise the lunar and solar calendars, the usual procedure is to intercalate extra lunar months from time to time. Finally, in order to synchronise the lunar calendar with the Moon there may also be a need to intercalate extra days in the lunar calendar (Gislén, 2018). The intellectual task of solving the intercalation problem has generated a host of interesting calendar variants and calculation schemes (Reingold and Dershowitz, 2018) and often stimulated the science of mathematics.

The Babylonians originally had an astronomical lunar calendar with months, which, like the Islamic calendar, started with the first visual observation of the New Moon crescent. This automatically synchronised the lunar calendar with the Moon. The synchronisation with the Sun was done by requiring that the start of the lunar year should not deviate too far from the spring equinox, and if it did, an extra lunar month was inserted and there was not in this respect a need for a separate solar calendar. From around the fourth century before the Common era (BCE), the Babylonians were able to predict the appearance of the New Moon by calculation and also switched to a more rigid system with seven intercalary lunar months in 19 solar years, inserted at fixed years 3, 6, 8, 11, 14, 17 and 19 in the 19-year cycle and giving a total of 235 lunar months in each 19-year cycle. This Metonic cycle is quite accurate: 19 tropical years of 365.2422 days are almost equal to 235 synodical months of 29.53059 days, where $19 \times 365.2422 = 6939.6018$ days, and $235 \times 29.53059 = 6939.6886$ days. The cycle has its name from the Greek astronomer Meton who lived in the fifth century BCE but it was known much earlier to Babylonian and Chinese astronomers. This reckoning gives a good synchronisation between the Sun and the lunar calendar. A similar scheme was inherited and used in the Jewish calendar and in some ancient Greek calendars. The advantage of a fixed computational scheme is that it is possible to plan and predict future events like gatherings and celebrations and thus serves as an important administrative tool.

All the regions of Southeast Asia had some kind of luni-solar calendar from around the seventh century, brought from India by Buddhist monks. The exception is Vietnam which was heavily influenced by Chinese luni-solar calendars. Indonesia early adopted a calendar that was close to the original Indian *Sūryasiddhānta* calendar (Eade and Gislén, 2000) but with a slightly different intercalation pattern. Quite early, around the sixth and seventh century in the Common era, Islamic traders visited Indonesia, being interested in the profitable spice trade. In the thirteenth century, Islam was spreading in the area, starting with northern Sumatra and the Malay Peninsula and replacing Hinduism. Other Indonesian areas gradually adopted Islam and by the sixteenth century it was the dominant religion in Java. Bali was the last region to retain a Hindu majority. In CE 1633, Sultan Agung formally inaugurated the Islamic calendar in Java but it had a slightly modified intercalation scheme as compared with the original Islamic calendar and was combined with the traditional five- and seven-week calendrical systems while retaining the Śaka era, CE 78. Burma, Laos, Thailand, and Cambodia, on the other hand retained calendars clearly inspired by India but with a more rigid way of intercalating months and days.

These calendars ceased to have official status in several mainland Southeast Asian states with the arrival of the European colonialism but are still used for cultural and religious festivals. The Gregorian calendar was adopted in Cambodia in 1863, in Burma 1885, and in Laos 1889. In 1888 it also became the official civil calendar in the independent Kingdom of Siam that today is Thailand and in 1954 the Gregorian calendar became the official civil calendar in Vietnam.

2 POLITICAL HISTORY

The political history of Southeast Asia is long and complicated. From early on, the Mainland was dominated by the Funan states, encompassing modern-day Cambodia, southern Vietnam, Laos and eastern Thailand, with different Hindu powers profiting from the trade between India and China. The maritime Southeast Asian trade was dominated by the powerful Srivijaya state. As its influence declined, the Khmer Empire expanded and experienced its golden age from the eleventh to the thirteenth century CE when it controlled the major part of the Mainland. In the east, in what is now central Vietnam, the Champā state ruled, and in the west from around CE 1050 the Pagan Kingdom in what is now Burma was on the rise. During the thirteenth century CE, the region experienced several Mongol invasions in Burma, Dai Viêt (present northern Vietnam) and Java that weakened or destroyed the established powers. The southern archipelago saw the rise of the Majapahiti Empire in eastern Java. This empire successively grew to control also the southern Malay Peninsula, Borneo, Sumatra, and Bali. Around CE 1200 the Thai state of Sukhothai in the north of present-day Thailand was created at the expense of the weakened Khmer Empire. Around CE 1350 the Thai states were united in the Ayutthaya Empire. At its peak it controlled the larger part of the Mainland, fighting frequent wars with the rival Khmer and the Burmese states. The Ayutthaya Kingdom lasted until about 1750 when it was destroyed by the Burmese. In the north, also aided by the decline of the Khmer Empire, the Lan Xang state rose in power and finally became what is now Laos. In maritime Southeast Asia, the Majapahiti state collapsed around CE 1500 and was replaced by Islamic sultanates in Java and on the Malay peninsula and finally most of what is present-day Indonesia was dominated by Islamic powers.

Dai Viêt was dominated by Chinese rule up to the middle of the tenth century. Until the French colonisation in CE 1858 it was, except for some shorter periods, independent and for much of the time ruled by different warlords and expanded southward. In 1471 the Vietnamese invaded and reduced the Champā state to a small enclave and many of its inhabitants fled to Cambodia.

Western influence started in the sixteenth century with the arrival of the Portuguese in Malacca. Throughout the seventeenth and eighteenth centuries the Dutch established the Dutch East Indies; the French Indochina; and the British Strait Settlements. By the nineteenth century all the countries in Southeast Asia were colonised except for Siam (Thailand). In World War II, Southeast Asia was invaded and occupied by the Japanese. After the war, Burma (Myanmar) became independent in 1948, Cambodia and Laos in 1953, Indonesia in 1945, Vietnam in 1976, and Malaysia in 1948.

Table 1: The Indian zodiacal signs.

Solar Month		English Translation	Associated Lunar Month	
Meṣa	मेष	Ram	Vaiśākha	वैशाख
Vṛṣabha	वृषभ	Bull	Jyeṣṭa	ज्येष्ठ
Mithuna	मिथुन	Twins	Āṣādha	अषाढ
Karka	कर्क	Crab	Śravaṇā	श्रवणा
Siṃha	सिंह	Lion	Bhādrapadā	भद्रपदा
Kanyā	कन्या	Virgin	Aśvina	आश्विन
Tulā	तुला	Balance	Kārttika	कार्त्तिक
Vṛścika	वृश्चिक	Scorpion	Mrgaśīrṣa	मृगशीर्ष
Dhanusa	धनुष	Bow	Pauṣa	पौष
Makara	मकर	Sea Monster	Maghā	मघा
Kumbha	कुम्भ	Water-carrier	Phālguna	फाल्गुन
Mīna	मीन	Fish	Caitra	चैत्र

3 INDIAN, CHINESE AND ISLAMIC INFLUENCES

3.1 Indian Influences

The roots of astronomy in India are very ancient. Some concepts certainly were introduced already in Vedic times, and there are indications of ideas coming from Hellenistic and Persian astronomy from around the times of the beginning of the Common era, especially in astrology. The Indian zodiacal names are direct translations of the Greek ones (Table 1). Many Indian astronomical terms can be traced to Greece, like Sanskrit *kendra*, *lipt*a from Greek *κέντρον*, *λεπτον*. Other influences may have come from Babylonia and China and certainly there are many independent Indian ideas. There is still an on-going and sometimes heated debate on the details of these roots. Indian astronomical ideas were transmitted to Southeast Asia and also to Nepal and China, and they influenced Muslim astronomers like al-Khwārizmī and al-Birūnī.

Most of the calendars in Southeast Asia, except the ones in Vietnam, are closely related to the original *Sūryasiddhānta* canon in India conceived around CE 500 by the mathematician-astronomer Aryabhāta (CE 476–550; Billard, 1971: 80, Mercier, 2012). This canon is different from the modern *Sūryasiddhānta* treated by Burgess (2000) which is a later improvement of the original canon. The modern *Sūryasiddhānta* uses updated values for the rotational periods and apogees of the Sun, the Moon, and the planets and a more involved model for the true longitudes. The backbone of the luni-solar calendar in the *Sūryasiddhānta* is a sidereal solar calendar, i.e. a calendar where the solar year is determined by the return of the Sun to the same location relative to the fixed stars, in contrast to the tropical year that is based on the return of the Sun to the vernal point, the crossing between the ecliptic and the celestial equator.

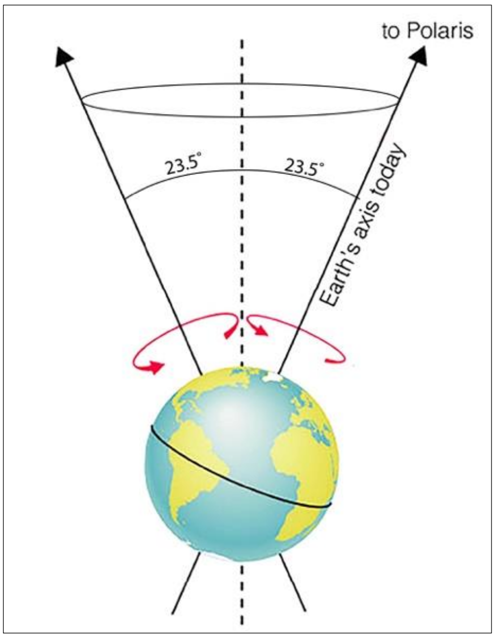

Figure 1: Precession of the equinoxes [diagram: Lars Gislén).

By the precession of the equinoxes, the vernal point is slowly receding westwards relative to the stars by about 1° in 72 years. This movement of the equinoxes is caused by the gravitational forces of the Sun and the Moon on the equatorial bulge of the Earth. These forces cause the rotational axis of the Earth to move like that of a spinning top on a table, tracing out a cone with an apex angle of close to 23.5° and with a period of about 26,000 years (Figure 1). Superimposed on this motion are much smaller deviations, the nutation, with shorter periodicity mainly due to the inclination of the lunar orbit relative to the ecliptic. These small deviations can be ignored in our context. The precession of the equinoxes was probably known already to the Babylonians but it was the Greek astronomer Hipparchus who around 130 BCE by his observations concluded that the rate of precession was about 1° per century. Ptolemy claims in the *Almagest* that he got precisely that value also from his observations (Toomer, 1984). The correction for precession from the time of Hipparchus, 266 years earlier, would then amount to 2° 40′. In reality the precession rate is about 1° in 72 years and the correction for precession should be 3° 40′, a difference of 1°, and indeed the longitudes of the stars in Ptolemy's star catalogue are in error by precisely this amount when compared with modern calculations. It is now (reluctantly) accepted that Ptolemy's star catalogue is a copy of an earlier, now lost, Hipparchean star catalogue that Ptolemy up-dated with his value of the precession although this conclusion has been hotly debated (e.g. see Grasshoff, 1990; Newton, 1977). When later Arabic and Persian astronomers measured the rate of the precession rate and found a larger value for it, they tried to explain this fact by inventing the erroneous hypothesis of the trepidation of the equinoxes, assuming that the equinoxes in addition to a constant motion also oscillated back and forth. The hypothesis of the trepidation of the equinoxes remained part of Medieval Western astronomy until the time of Kepler. In Indian astronomy the precession rate is described by a zig-zag function with a period of 3,600 years and an amplitude of 27°. When day length, shadows and parallax in solar eclipses are calculated it is necessary to use tropical ecliptic longitudes, i.e. sidereal longitudes corrected for precession.

The sidereal year is slightly longer than the tropical year, its current value being 365.25626 days, while the tropical year has 365.2422 days. The early Indian calendar that will be considered here, uses a sidereal year of 365.25875 days (Billard, 1971: 75), where the basis of this reckoning is the assumption that the Sun makes 4,320,000 circuits (*bhagaṇa*) around the Earth in 1,577,917,800 days, the *mahayuga*. The epoch of this calendar, the *Kaliyuga* era, is midnight at Ujjain on 18 February CE –3,101 (3102 BCE),[3] Julian Day 588465.5.[4] Ujjain is the prime meridian or Greenwich of India, situated at longitude 75.8° E and latitude 23.2° N in the state of Madhya Pradesh. At epoch the Sun, the Moon and the planets were all assumed to have mean longitude zero. In the early version of the Indian calendar, each solar month starts when the Sun's mean sidereal longitude reaches a multiple of 30°, i.e. when the mean Sun enters a new zodiacal sign. This aligns the solar calendar with the mean Sun and results in twelve solar months, each with the same length of 365.25875/12 = 30.43823 days. The entry of the mean Sun in a zodiacal sign can occur at any time of the day but the civil solar month starts on the following sunrise.

The *Sūryasiddhānta* lunar calendar was in early times based on the mean synodic month. The lunar sidereal motion is expressed as the Moon making 57,753,336 sidereal circulations in 1,577,917,800 days. This means that relative to the Sun, the Moon makes 57,753,336 – 4,320,000 circulations, i.e. each circulation takes 1,577,917,800/(57,753,336 – 4,320,000) = 29.530587 days, the length of the mean synodic month. This is a very accurate value; the present current value is 29.530589 days. A synodic month starts when the Moon and the Sun have the same longitude, at New Moon, or in some parts of India when the Moon is opposite to the Sun, at Full Moon. The name of the lunar month is associated with the solar month in which the lunar month starts (see Table 1). As with the solar month the lunar month can start at any time of the day but the civil lunar month starts on the following sunrise. The fact that the mean synodic month is shorter than the mean solar month means that there will sometimes be two lunar months starting in the same solar month, i.e. a second New Moon at a time when the Sun is still in the same sign as at the previous New Moon. The first of these two months is then an intercalary month, *adhikamasa* but will otherwise have the same name as the second month. In this way there will be a lunar month intercalation when it is needed and the synchronisation between the solar and lunar calendars will be automatic.

Figure 2 illustrates the system of month intercalation. Lunar month 1 begins in solar month A and will get the lunar month name associated with solar month A. Likewise lunar month 2 will start in solar month B and get the corresponding name. However, lunar months 3 and 4 both begin in solar month C and will both get the name associated with C, the first of these lunar months with the name prefixed by the word *adhika*. Lunar month 5 starts in solar month D and will get the name associated with this month.

In Southeast Asia the system was changed, such that the extra month was confined to the

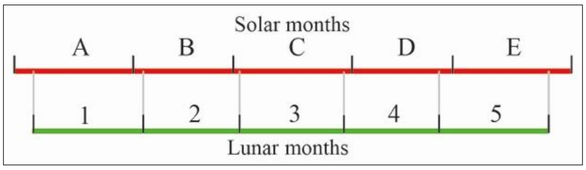

Figure 2: Month intercalation (diagram: Lars Gislén).

first (in the Arakanese calendar) or fourth month (in the Makaranta, Thandeikta, and Thai calendars) of the lunar year.

An important quantity in Indian astronomy is the *tithi,* or lunar day, a time interval being 1/30th of a synodic month, a concept found already in Babylonian astronomy, a *tithi* being the time it takes for the distance between the Sun and the Moon to increase by 12°. The *tithi* can also refer to the position of the Moon relative to the Sun in terms of these 12° intervals. The *tithis* are numbered from one to fifteen waxing (*śukla*), the fifteenth being Full Moon, *purṇima*, then from one to fifteen waning (*kŗşṇa*), the last day being *amāvāsya*, New Moon (see Table 2). The lunar days in a lunar month are denoted by the number of the *tithi* in force at sunrise. As the mean *tithi* is shorter than a civil solar day, there will occasionally be a *tithi* that is not in force at sunrise of the morning of any day in the month. The *tithi* is then suppressed and that lunar month will have only 29 days. This procedure will align the lunar calendar with the (mean) Moon.

Later, true solar and lunar months and days were introduced in the Indian luni-solar calendar. The length of both the solar and lunar month then varied, making the intercalation system mathematically more complicated but still using the same principle for intercalation. One consequence of using true longitudes is that, very rarely, there is no lunar month starting in a solar month and then the corresponding lunar month is suppressed, *kṣayamasa*. Also, in some rare cases a *tithi* will be assigned to two solar days. In the modern Indian luni-solar calendar there are some amendments to the canonical parameters, the number of days in the modern *Sūryasiddhānta* in a *mahayuga* is for instance 1,577,917,828 resulting in a slightly longer sidereal year.

Table 2: *Tithi* and *karana* names.

Tithi	*Karana*	*Tithi*	*Karana*	*Tithi*	*Karana*
1: Pratipadā śukla	Kiṃstughna-Bava	11: Ekasaśī śukla	Vaṇija-Viṣṭi	21: Saṣṭhī kŗşṇa	Gara-Vaṇija
2: Dvitīya śukla	Vālava-Kaulava	12: Dvādasī śukla	Bava-Vālava	22: Saptamī kŗşṇa	Viṣṭi-Bava
3: Tṛtīya śukla	Taitila-Gara	13: Trayodaśī śukla	Kaulava-Taitila	23: Astamī kŗşṇa	Vālava-Kaulava
4: Caturthī śukla	Vaṇija-Viṣṭi	14: Caturdaśī śukla	Gara-Vaṇija	24: Navamī kŗşṇa	Taitila-Gara
5: Pañcamī śukla	Bava-Valava	15: Purṇima	Viṣṭi-Bava	25: Dasamī kŗşṇa	Vaṇija-Viṣṭi
6: Saṣṭhī śukla	Kaulava-Taitila	16: Pratipada kŗşṇa	Vālava-Kaulava	26: Ekasaśī kŗşṇa	Bava-Vālava
7: Saptamī śukla	Gara-Vaṇija	17: Dvitīya kŗşṇa	Taitila-Gara	27: Dvādaśī kŗşṇa	Kaulava-Taitila
8: Astamī śukla	Viṣṭi-Bava	18: Tṛtīya kŗşṇa	Vaṇija-Viṣṭi	28: Trayodaśī kŗşṇa	Gara-Vaṇija
9: Navamī śukla	Vālava-Kaulava	19: Caturthī kŗşṇa	Bava-Vālava	29: Caturdaśī kŗşṇa	Viṣṭi-Śakuni
10: Dasamī śukla	Taitila-Gara	20: Pañcamī kŗşṇa	Kaulava-Taitila	30: Amāvāsya	Nāga-Catuṣpada

Table 3: *Naksatra* names.

Nakṣatra		
1: Aśvinī	10: Maghā	19: Mūla
2: Bharaṇī	11: Purvaphalgunī	20: Purvāṣaḍhā
3: Kṛttikā	12: Uttaraphalugī	21: Uttarāṣaḍha
4: Rohiṇī	13: Hasta	22: Śravaṇā
5: Mṛgaśiras	14: Citrā	23: Daniṣṭha
6: Ardrā	15: Svāti	24: Śatabiṣaj
7: Punarvasū	16: Viśākhā	25: Purvabhadrapadrā
8: Puṣya	17: Anurādhā	26: Uttarabhadrapadrā
9: Āśleṣā	18: Jyeṣṭhā	27: Revatī

Much of the astronomical Indian Sanskrit or Pali technical terminology has passed over to the Southeast Asian astronomy, the Indian *ahargaṇa*,[5] the number of elapsed days from the epoch, for instance, becomes *horakhun* in Thailand and Laos and *haragon/tawana* in Burma. The Indian origin of the Southeast Asian names of the solar and lunar months can often easily be recognised. The terms *rasi*, *angsa*, and *lipta* for zodiacal signs, degrees, and minutes of arc are Indian heritage (Gislén and Eade, 2020).

Also inherited from India in Southeast Asia are the concepts of *tithi*, *nakṣatra*, and *yoga*. The *nakṣatra* gives the position of the Moon relative to the stars, the ecliptic now being divided into 27 parts, each spanning 13° 20′. This agrees approximately with the *Sūryasiddhānta* sidereal period of the Moon 1,577,917,800 / 57,753,336 = 27.32167 days. Finally, the *yoga* is an artificial construction, being the sum of the longitudes of the Sun and the Moon, used in astrology and with the same division into 27 parts as the for the *nakṣatra*. The Thai term for the *nakṣatra* is *rœk* and the Burmese term is *nekkhat*. The Indonesian records use the Indian names for the *nakṣatras*, and *yogas* (see Tables 3 and 4). Each *tithi* is further divided into two *karanas* (see Table 2). Other examples of Indian influence are the division of the day (24 hours) into 60 *nadi,* Thai *nathi*, Burmese *nayi*, each *nadi* being subdivided into 60 *vinadi/ vinathi/bizana*, and the concept of *lagna*, the ascendant or the rising sign of the zodiac.

The *Sūryasiddhānta* canon also contains parameters and algorithms for the calculation of the sidereal longitudes of the planets, for the lunar node (Rahu) and apogee and for a fictive body, Ketu, that in Southeast Asian astronomy orbits the sky with a speed ten times that of Rahu and in the same retrograde direction. These computational schemes are taken over by several of the Southeast Asian calendars, albeit with somewhat simplified parameters.

Table 4: *Yoga* names.

Yogas		
1: Viṣkamba	10: Gaṇḍa	19: Parigha
2: Prīti	11: Vṛddhi	20: Śiva
3: Āyuṣmat	12: Dhruva	21: Siddha
4: Saubhāgya	13: Vyāghāta	22: Sādhya
5: Śobhana	14: Harṣaṇa	23: Śubha
6: Atigaṇḍa	15: Vajra	24: Śukla
7: Sukarman	16: Siddhi	25: Brahman
8: Dhṛti	17: Vyatipāta	26: Indra
9: Sūla	18: Varīyas	27: Vaidhṛiti

Both the Burmese and Thai calendars use a period of 800 years containing 292,207 days for the Sun. This is nothing but the *Sūrya-siddhānta* canonical numbers 4,320,000 and 1,577,917,800 divided by 5,400 and is an obvious heritage from India. Most of the Indian-influenced calendars in Southeast Asia use the notation of elapsed years, the first year of the era being zero.

3.2 Chinese Influences

The Chinese calendar is very old, having roots back in the fourteenth century BCE and there have been more than 50 calendar reforms since then (Reingold and Dershowitz, 2018). It is a luni-solar calendar based on astronomical events, not on arithmetical rules, involving the longitudes of the Sun and the Moon. This calendar has had a strong influence on those of Korea, Japan and Vietnam and also to some extent on the Tibetan calendar. Since CE 619 true longitudes have been used for the Moon and since CE 1645 also for the Sun. The version described below is the CE 1645 implementation taken from Reingold and Dershowitz (ibid.).

The Chinese year consists of lunar months where the arrangement of these months depends on the position of the Sun in the zodiac. The Chinese zodiac is divided into 24 solar terms each corresponding to a 15°-segments of which there are 12 major solar terms starting at the beginning of the zodiacal signs and 12 minor terms starting at the middle of the signs. A solar month then consists of one major and one minor term. The dates and times for these solar terms depend on when the Sun enters the respective terms which in turn depends on the geographical longitude adopted for the calendar. Before CE 1929 the Chinese calendar used the meridian of Beijing as the prime meridian, after that the meridian for Chinese standard time, UTC + 8 hours has been used. The solar term corresponding to the winter solstice determines the intercalation of lunar months in the calendar. Between two winter solstices there can be either twelve or thirteen new Moons, in the latter case there will be an intercalary month, otherwise the year will be a normal one with twelve lunar months. Chinese lunar months begin at New Moon on midnight of the day at the prime meridian. The arrangement of the lunar months is determined by the rule that the winter solstice always occurs during the eleventh month. There is a second rule for an intercalary year that determines that the intercalary lunar month should be the first month that is wholly within a solar month. An equivalent formulation of the rule is that if two lunar months start in the same solar month, the first one will be intercalary. In this formulation it is identical to the rule for an intercalary month in the Indian calendar. As the calendar is astronomical it is automatically synchronised with the Sun and the Moon and the winter solstice rule will align the solar and lunar calendars. In China the required calculations were made by the imperial astronomers. There were many reforms of the calendar, each new dynasty changing the intercalary rules in order to be seen to make the calendar more perfect.

The Vietnamese calendars have many similarities with the Chinese calendar but with some substantial differences. The other calendars in Southeast Asia have less Chinese influence except in the use of sexagesimal cycles. In Northern Thailand sexagesimal cycles are used for days and years that show a great similarity to the Chinese sexagesimal year cycle built on a combination of a 10- and a 12-year cycle. The year names in the 12-year cycle are the same as the Chinese ones except for the last one that is sometimes 'Elephant' instead of 'Pig' (Davies) and in Vietnam 'Rabbit' is changed to 'Cat'. It seems that these names, originally Chinese, were borrowed from Old Vietnamese into the Khmer language during the pre-Angkor era and then spread to the Thai region (Ferlus, 2013). However, the Thai decimal cycle names differ from the corresponding Chinese ones and seem to have a separate origin. The sexagesimal day cycle in Northern Thailand is also combined with the seven-day week cycle to create a 420-day cycle. This is a very valuable dating complement in cases where calendrical records are accompanied by sexagesimal information. In Burma there is also a 12-year cycle but there the years take the names of the Indian lunar months.

3.3 Islamic Influences

The original Islamic calendar is a purely observational and strictly lunar calendar. The start of each month is determined by the first sighting in the evening of the New Moon crescent. The year contains twelve lunar months. There is no cyclical intercalation of months or days. The mean year length is a little more than 354 days which means that it is not fixed in relation to the seasons and the solar year but migrates through the solar year over a period of about 32 years. The epoch of the calendar is CE 16 July 622, the exit from Mecca by the prophet Mohammad.

The observer-based foundation of the calendar presented some problems when Islam and the calendar was introduced in regions with a larger time difference from the Middle East and thus created observational differences in the start of the months and in many places a modified arithmetic Islamic calendar was used. This calendar has a fixed set of twelve months with alternate 30 and 29 days and a 30-year cycle for the intercalation of an extra day in eleven years, added to the last month. The intercalary years are the cyclic years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26, and 29 (Reingold and Dershowitz, 2018). Some Muslims use the cyclic year 15 instead of 16. The Islamic calendars adopted in the Southeast Asia archipelago introduced still more variants trying to adapt the calendar to the traditional cyclic 7- and 5-week patterns of the region.

4 CONCLUDING REMARKS

Calendars are an interesting feature of Southeast Asian nations not least because they reveal the influences of the flanking powers, China and India, but also display their own distinctive local innovations. Calendars are intimately connected with religious and other festivals and commemorations as well as with agriculture and are often defended fiercely as part of the cultural tradition against foreign influence and are sometimes used to express dominance. The calendar reform in Europe in 1582, introduced by Pope Gregory XIII to replace the Julian calendar with the Gregorian one, was considered as a kind of Papist plot by the Protestant countries and it took about two centuries to be accepted by them.

The heritage from India in the Burmese, Thai and Maritime Southeast Asia early calendars is substantial. However, the astronomy and calendar schemes in India have a theoretical astronomical basis while schemes in Southeast Asia are built on a set of arithmetic computational rules with little explanation. Chinese influence on the calendars of Southeast Asia is generally weak with the exception of the Vietnamese calendar. Elements of a Chinese sexagesimal cyclic reckoning for years and days can be seen in northern Thai and Laos. The states in the Southeast Asian archipelago successively adopted a modified version of the Islamic calendar starting around the fifteenth century in the Common era.

5 NOTES

1. For specialist astronomical terms used in this paper see the Glossary in Section 7.2.
2. The Persian arithmetic calendar with an intricate leap year pattern following a cycle of 2820 years is at present the best emulation of the tropical year (Reingold) and is asserted to have an error of only a couple of minutes in 2820 years.

3. There are two ways of expressing years before the Common (or Christian) Era. Historians use the system that the years before CE 1 come 1 BCE, 2 BCE and so on. The astronomical system uses negative years; the years before CE 1 are CE 0, CE –1, CE –2 and so on. Thus, mathematically *n* BCE = – (*n* – 1) CE.
4. This epoch appears in the Alfonsine Tables as 'Diluvio', i.e. the Flood. Meanwhile, for more information about Julian days see Section 7.1, below.
5. The transcription of the many technical terms in Sanskrit, Pali, Burmese, Thai, and Khmer presents some problems. The principle, although not strictly adhered to, has been to write such terms in italics and with diacritics the first time they appear but in plain font and without diacritics afterwards. In a few cases also Burmese and Thai scripts have been used. In most cases the Sanskrit/Pali terms has been retained.

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7 APPENDICES

7.1 The Julian Day and the Equation of Time

The Julian Day is a tool used in chronology in order to uniquely tag a historical event. It was introduced by the French scholar Joseph Scalinger (1540–1609). Julian Days are counted starting with zero from the epoch at Universal Time (UT) 12 hours, 1 January 4713 BCE in the proleptic Julian calendar. The epoch is sufficiently far back in time for any meaningful historical record to have a positive Julian Day. Any date in any calendar can be converted to a Julian Day, something that is very useful in conversions between different calendars. For instance, the Gregorian calendar date UT 15:11, 26 March 2019, corresponds to Julian Day 2458569.127 where the fraction gives the time of the day counted from noon.

The time of the day today is given as standard mean solar time referred to a standard meridian and is the time shown by clocks. It is based on a fictitious mean Sun moving along the celestial equation with uniform speed. Mean noon is defined as the time when the fictitious Suncrosses a selected standard meridian where the Earth is divided into a number of standard time zones each with its standard meridian. However, the time used in civil practice until the middle of the nineteenth century was apparent local solar time where noon is defined as the time when the true Sun crosses the local meridian. The true Sun differs in two ways from the fictitious Sun. It moves along the ecliptic that is inclined to the celestial equator by an angle of about 23.5°, the obliquity. Secondly, because of the ellipticity of the orbit of the Earth, the movement of the Sun in the ecliptic is not uniform but varies during the year being fastest in January and slowest in July. The reason for using apparent local solar time is that in an epoch where mechanical clocks were rare, not very reliable or non-existent, one of the few ways to setting time was using the local meridian passage of the real Sun. The records of Southeast Asia in general are based on local apparent solar time. This was also the practice in Western astronomy until the end of the seventeenth century. Although in most cases the difference between apparent and mean solar time can be ignored, it can sometimes be critical for the interpretation of a record for example when time is referred to true sunrise.

The difference between apparent solar time and mean solar time is called *the equation of time*. Before CE 1833 it was standard to use a definition of the equation of time with the opposite sign: mean solar time minus apparent solar time. The equation of time is a function of the day of the year and has a variation of about ±15 minutes. It also has a slow secular variation that

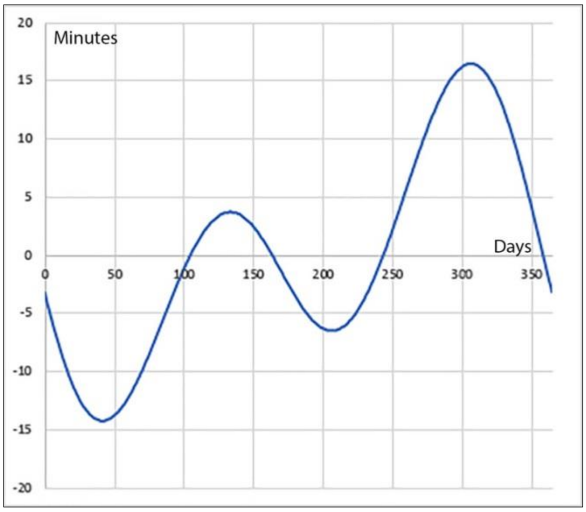


Figure 3: The equation of time (after Meeus, 1998).

can be neglected in this context. Figure 3 shows a graph with the current equation of time as a function of day of the year.

7.2 Glossary

ahargaṇa The number of elapsed days since the epoch.

angsa An Indian term for one zodiacal degree of arc.

*Aryabhāt*a Famous Hindu astronomer and mathematician who lived CE 476–550. He is the author of two important Indian canons: the *Sūryasiddhānta* and the *Aryabhātiya*.

Ayutthaya Kingdom A Siamese kingdom that existed from CE 1350 to 1767. The court of King Narai (1656–1688) had strong links with that of King Louis XIV of France.

Champa State A State extending along the coast of what is today central and southern Vietnam from approximately the second century CE until being finally absorbed and annexed by the Vietnamese Emperor Minh Mang in CE 1832 .

CE, Christian era The common era used in the Western Word. Its epoch is Julian Day 1721423.5.

Đại Việt The name of Vietnam for the periods CE 1054–1400 and CE 1428–1804.

equation of time The correction to be applied to mean solar time to get apparent solar time.

equinox The time when the Sun passes the equator. On the equinox the day and night are equally long.

Gregorian calendar The present calendar in most of the non-Islamic world and introduced in CE 1582 by Pope Gregory XIII. It is a solar calendar with normal years of 365 days and leap years with 366 days. In intercalates a leap day when the year is divisible by 4 except for century year where the century year is not divisible by 4. The mean length of this year is 365.2425 days. The epoch is CE 1 January 1.

heliacal rising The first day when the star (after a period when it was invisible) rises in the morning before the Sun and the Sun is still far enough below the eastern horizon to make it briefly visible in the morning twilight.

Islamic calendar A purely lunar calendar with twelve lunar months, each month beginning with the first sighting of the New Moon crescent in the evening. The epoch of the calendar, Hidjra or Hegira is CE 2 July 622 (Julian). Often used is the tabular Islamic calendar that has normal years of 354 days with 12 months with alternating lengths of 30 and 29 days and leap years with the last month having an intercalary day. The intercalation is governed by having 19 leap years in 30 years governed by a fixed sequence.

Julian calendar The Western calendar used before the introduction of the *Gregorian calendar*. It has a normal year with 365 days and leap years with 366 days, leap years being years that are divisible by 4. The mean length of the year is 365.25 days. The epoch is the same as for the Gregorian calendar, CE 1 January 1.

Julian Day A quantity, not having any relation with the Julian calendar, used by calendarists in order to have a unique number for each day. The epoch is noon 1 January 4713 BCE when the Julian Day number is 0. The epoch is sufficiently remote for historical dates to have a positive Julian Day number. A Julian Day starts at noon. It is a very convenient tool when studying relations between different calendars.

Kaliyuga epoch An epoch is used in Indian astronomy and is 18 February 3202 BCE. In the *Sūryasiddhānta* canon it is counted from midnight, in the *Aryabhātiya* canon from sunrise or 6 a.m.

Ketu An artificial celestial body in Southeast Asian astronomy moving with ten times the speed of Rahu and with only astrological significance. In Indian astronomy it is normally the descending node of the Moon.

Khmer Empire Conventionally the epoch of the Khmer Empire is dated CE 802. At its height it controlled the major part of the SE Asian Mainland. The Empire ended with the fall of Angkor in the fifteenth century.

kṣayamasa An Indian term for the suppression of a lunar month, something that can happen when true longitudes of the Sun and the Moon are used in the Indian calendar.

Lan Xang This was a Lao Kingdom that existed from CE 1354 to 1707. It was one of the largest kingdoms in SE Asia and the precursor of present-day Laos.

lipta Indian term for minutes of arc. Of Greek origin, *λεπτον.*

mahayuga A time period used in Indian astronomy. It is a period of 4,320,000 solar years, in the *Sūryasiddhānta* canon consisting of 1,577,917,800 days, in the *Aryabhātiya* canon of 1,577,917,500, and in the modern *Sūryasiddhānta* canon of 1,577,917,828 days.

Majapahiti Empire A thalassocracy based on the island of Java that existed from CE 1293 to about 1500. During its height it extended from Sumatra to New Guinea.

mangsa An Indonesian agricultural solar calendar.

Metonic cycle A 19-year intercalation cycle for lunar months, used already by the Babylonians but being named after the Greek astronomer Meton who lived in the fifth century BCE.

nadi An Indian time measure with 60 *nadi* in a day and night. In Thai it is *nathi* and in Burmese *nayi*. It corresponds to 24 minutes.

nakṣatra A measure of the Moon's longitude where the zodiac is divided into 27 parts, each covering 13° 20′. In Thai it is called *rœk* and in Burmese *nekkhat*.

Pagan Kingdom The first kingdom to unify the regions that would later be the present-day Burma. From around the ninth century it expanded from settlements at Pagan. At the end of CE 1200 it was subject to several Mongol invasions.

Pawukon A Balinese cyclic calendar based on a combination of periods with one-, two-, three-,…, and ten-day 'weeks' generating a repeating 210-day period.

precession of the equinoxes Due to the gravitational influence of the Sun and the Moon on the equatorial bulge of the Earth, the rotation axis of the Earth will trace out a cone similar to that of a spinning top on a table. This will cause the vernal equinox of the ecliptic to move slowly backwards along the celestial equator.

precession rate This is the rate of change in tropical longitudes due to the precession of the equinoxes, about 1° in 72 years.

Rahu The entity known in the West as the 'Dragon's Head'. The plane of the Moon's orbit is inclined to the Earth by about 5°. From this it follows that there are two points, opposite each other: one where the Moon passes from having a southern or negative latitude to having a northern and positive latitude (the 'Head'); and one where it passes from north to south (the 'Tail'). These points are called the lunar nodes, respectively the ascending and the descending node, and they rotate slowly in a direction opposite to the direction pursued by the planets; i.e., the nodes have a decreasing longitude, not an increasing one. In SE Asian astronomy Rahu is considered a separate planet.

rasi An Indian term corresponding to the Western zodiacal sign.

sexagenary cycle A cycle generated by combining a ten-year cycle with a twelve-year one. In SE Asia it is generated by combining items with the same parity (odd-odd or even-even). It is similar and in some respects identical with the corresponding Chinese sexagenary cycle, the names of the years in the twelve-year cycle are identical to the Chinese ones. In the early Thai calendar, it is commonly used for both days and years, in Burma only for years in the twelve-year cycle and using the names of the Indian lunar months.

sidereal year A solar year defined by the time for the Sun to reach the same point relative to the stars. This is in contrast to the *tropical year* which uses the time for the Sun to return to vernal equinox. Due to the precession of the equinoxes these two years will be slight different in length. SE Asian astronomy is based on the sidereal solar year. The original *Sūryasiddhānta* sidereal year has 365.25875 days, for the modern *Sūryasiddhānta* has 365.2587648 days. The present modern value is 365.256363 days.

Srivijaya A city-state based in Sumatra and dominating the Indonesian archipelago between the seventh and eleventh centuries CE. In the thirteenth century it collapsed, mainly due to the expansion of the *Majapahiti Empire*.

Sukhothai A Thai state that grew out of several smaller states when the influence of the Khmer Empire declined. At the end of CE 1200 it controlled most of what is today Thailand. After that it rapidly decayed into Lao states in the north, Mon states in the west, and finally in CE 1378 the Ayutthaya Kingdom conquered the remains.

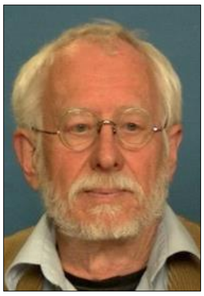
Sūryasiddhānta Indian canons. There are two canons with the same name. The original *Sūryasiddhānta* or here simply the *Sūryasiddhānta* was conceived by the Hindu astronomer Aryabhata around CE 500, while the modern *Sūryasiddhānta*, treated by Burgess, is an updated version of the original and dates from around CE 1200.

synodic month The time for the Moon to return to the same position relative to the Sun. It has a mean value of about 29.5 days.

tithi Originally a time unit being a lunar day or 1/30th of a synodic month, in SE Asian astronomy being 692/703 of a solar day. It can also refer to the lunar day number in a month and also the relative position of the Moon relative to the Sun, the possible 360° divided into 30 *tithis*, each one covering 12°. This unit of time was used already by the Babylonians.

trepidation of the equinoxes A concept invented by Medieval astronomers to explain the observed change in celestial longitude of the stars as compared with those in Ptolemy's start catalogue in Almagest. It assumes that the equinoxes on top of a constant precession rate also have an oscillating movement back and forth. It was part of Western astronomy up to the time of Kepler. The Indian version assumes a zig-zag motion with an amplitude of 27°and a period of 7200 years.

tropical year The time for the Sun to return to the vernal equinox. The current mean length of the tropical year is 365.24219 days.



Dr Lars Gislén is a former lector in the Department of Theoretical Physics at the University of Lund, Sweden, and retired in 2003. In 1970 and 1971 he studied for a Ph.D. in the Faculté des Sciences, at Orsay, France. He has been doing research in elementary particle physics, complex systems and applications of physics in biology and with atmospheric physics. During the past twenty years he has developed several computer programs and Excel spreadsheets implementing calendars and medieval astronomical models from Europe, India and Southeast Asia (see http://home.thep.lu.se/~larsg/).

Dr Chris Eade has an M.A. from St Andrews and a Ph.D. from the Australian National University. In 1986 he retired from the Australian National University, where he had been a Research Officer in the Humanities Research Centre before moving to an affiliation with the Asian Studies Faculty, in order to pursue his interest in Southeast Asian calendrical systems. In particular, research that he continued after retirement concerned dating in Thai inscriptional records, in the horoscope records of the temples of Pagan and in the published records of Cambodia and Campa.