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THE ASTRONOMICAL ORIENTATION OF THE THAI PHRA THAT DOI SUTHEP TEMPLE IN RELATION TO THE ACRONYCHAL RISING OF ALPHA CORONA BOREALIS AND *VISAKHA BUCHA* DAY

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Abstract: Astronomical orientation of ancient sites can reveal astronomical wisdom utilized to resonate with the context of the maker, thus providing additional insight into that ancient culture. In this study, the orientation of Phra That Doi Suthep Temple, a sacred Buddhist temple that was founded during the prosperous period of the ancient Lanna Kingdom (in Chiang Mai, in present-day Thailand), was investigated, as well as its connection to the tradition that many Buddhists walk up the mountain to the temple on the eve of *Visakha Bucha* Day (*Vesak* Day—the Full Moon day of Vishākhā month). The remaining traces of historical evidence, including ethnic astronomical practices, suggest that the alignment of the temple when it was founded may have been related to the constellation now known as Corona Borealis (CrB), where α CrB is the reference star for the Vishākhā *Nakṣhatra*. To investigate this deduction, we surveyed the temple's orientation using a theodolite and GPS, to obtain the azimuth of 59.74 ± 0.07° (30.26 ± 0.07° north of east). We employed *Stellarium*, which is precession-corrected, to determine the azimuth of α CrB and simulated that back in time to match that of the temple, thus yielding the estimated planning years. The finding suggests that the temple might be oriented to the true acronychal rising of α CrB in AD 1537 ± 19 in order to manifest the Full Moon on *Visakha Bucha* Day (a traditional Buddhist calendar's New Year's Day), close to the time when King Mueangketklao of Lanna reconstructed the temple on 21 April 1538.

Keywords: Wat Phra That Doi Suthep, *Visakha Bucha* Day, α Corona Borealis, temple orientation

1 INTRODUCTION

Many ancient sites around the world are the manifestation of hidden astronomical alignments that were utilized to resonate with cultural products, such as calendrical systems or sacred rituals (Castro et al., 2016). Temples, monuments, palaces, and mysterious ruins, e.g., Egyptian temples, Stonehenge in Britain, and the Forbidden City in Beijing, have been discovered with astronomical significance (Boutsikas, 2015). The common astronomical tools for alignment involve the use of solstices, equinoxes, the Moon, bright classical planets, or bright fixed stars with respect to the position of the Sun or the Moon (Magli, 2013: 25–30). In this paper, we investigate the astronomical orientation of Phra That Doi Suthep Temple situated on top of Doi Suthep Mountain in Chiang Mai, Thailand. This temple is regarded as the most revered Buddhist temple built around the period of the ancient Lanna Kingdom, thus the findings of this study may offer some insight on the astronomical wisdom of ancient Lanna culture.

To form an hypothesis about the utilized astronomical alignment, the ethnoastronomical background of the nearby region was taken into consideration. The Khmer Empire that existed across much of Southeast Asia was a Hindu-Buddhist kingdom that included Cambodia, lower northeastern Thailand, and southern Vietnam. Consequently, many spectacular Khmer sanctuaries can be found in present-day Thailand, such as Prasat Phanom Wan, Prasat Hin Phimai, Prasat Hin Phnom Rung, and others, which were erected in the same general period as Angkor Wat (during the ninth to the fifteenth centuries CE). Komonjinda et al. (2019) has

suggested that the orientation of Prasat Hin Phanom Rung, a Khmer Hindu temple in Buriram, Thailand, was related to the cosmical setting of Spica (α Virginis) on Saka's New Year's Day. The temple's main axis might be marked by the starting point of *Meṣa Rāśi* (Aries) in opposition to Spica. This result suggests that the azimuth of some notable stars with which ancient buildings were aligned can be used to roughly estimate the founding date of ancient structures. Remarkably, the tradition of walking up to the Phnom Rung temple that used to take place on the Full Moon of the fifth Thai lunar (*Chitrā*) month (now it is changed to the beginning of April), is also concurrent with the day when the cosmical setting of Spica occurred in ancient times.

As a Buddhist temple, Phra That Doi Suthep Temple bears several similarities to the Great Stupa of Sanchi in India. The orientation of stupas at Sanchi in the Raisen District of Madhya Pradesh has been investigated by Rao (1992). The religious center at Sanchi was located on a hill, and was founded by Emperor Asoka in the third century BC. He erected the Great Stupa, which served as the first nucleus of the Buddhist religious center. Originally, the stupa was a simple hemispherical brick structure that was believed to represent Buddha since it housed the relics of Lord Buddha; thus, the stupa's orientation might be based on events in the Buddha's life. According to investigations, the Great Stupa could have been orientated toward the moonrise and sunset on the day of Buddha Purnima. The commemoration of that day was reckoned as the Buddhist *Nirvāṇa* Era, as found in many Lanna scripts (more details given in Section 1.1). Such a day is currently known as *Visakha Bucha* Day in Thailand, and is described in Section 1.3.

The proposed orientation of Phra That Doi Suthep Temple, the most sacred Thai Buddhist place on top of a mountain with Buddha's relics, is based on two main observations:

(1) the temple faces north of east by a large degree that is beyond the possible azimuths of the Sun and Moon; and
(2) the temple has a similar tradition to the Sanchi Great Stupa with devotees walking up the mountain to enshrine the relics on the eve of *Visakha Bucha* Day.

Therefore, it is possible that the Phra That Doi Suthep Temple's orientation is associated with a bright star that marks *Visakha Bucha* Day, which is the beginning of the Buddhist calendar.

According to our research, several Lanna astrological charts and records show that the *Vishākhā Nakṣhatra*, in which the Full Moon on *Visakha Bucha* Day is located, was associated with either Corona Borealis, Libra, or the stars in Scorpius (see details in Section 1.3). However, only the azimuth of Corona Borealis on the horizon was probably aligned to the orientation of the Phra That Doi Suthep Temple. Therefore, the azimuth of Corona Borealis was investigated and evaluated back to the time when the temple was founded. Historical records relating to the construction of the Phra That Doi Suthep Temple also provided a reference for such a founding date, and are examined in Section 1.4. Furthermore, as discussed in Section 1.5, many Lanna temples are found to be oriented in relation to the zodiac constellations.

1.1 The Buddhist Calendar in Thailand: Historical Background

The history of the Indian calendar from the end of the *Yajurveda* period (1300 BC–AD 300) to the beginning of the *Siddhanta Jyotisa* period (about AD 500) is imperfectly known although there are numerous calendric references in the Brahmanas, Buddhist Sutras, and epic Mahabharata, among other places (Saha and Lahiri, 1992: 221–241).

The Buddhists of Ceylon (presently Sri Lanka), generally credit Ashoka's son Mahinda (285–205 BC) with introducing Buddhism to Sri Lanka, and he was later remembered as a founding missionary of the country's majority religion. One of the local Buddhist calendars used the Buddhist *Nirvāṇa* Era epoch in 544 BC—in contrast to most antiquarians placing the *Nirvāṇa* in 483 BC and present Thailand's Buddhist Era epoch in 543 BC—has been used since the first century BC (Saha and Lahiri, 1992: 256–257). Subsequently, Sri Lanka's (Sinhalese) Theravada *Mahavihara* tradition spread throughout the rest of Southeast Asia, including Myanmar, Thailand, Cambodia and Laos.

By the end of the thirteenth century, Buddhism had been established in the region now known as Thailand, which was made up of many independent Buddhist kingdoms, such as the Lanna, Sukhothai and Ayutthaya Kingdoms. An inscription engraved on Face 2 at Pho Khun Ram Khamhaeng shows that the Sukhothai King Ramkhamhaeng (r. 1279–1298) was a great supporter of Theravada Buddhism, and he invited chief Buddhist monks from Nakhon Si Thammarat (now a province in Southern Thailand) to teach the Dhamma discipline in the capital city, Sukhothai (Princess Maha Chakri Sirindhorn Anthropology Centre, 2012). The

Wat Sema Mueang Inscription on Face 1, discovered in Nakhon Si Thammarat, records the year 697 in *Mahasakaraj* or Saka Era (AD 775) and the solar month *Madhava*, which corresponds to the lunar *Vishākhā* month (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021a). The word *Madhava* was found in usage in the old system of the twelve Buddhist solar and lunar months, which had probably been taken from the *Yajurveda* (ca. 1200–800 BC) (Saha and Lahiri, 1992: 182, 218–220).

A half-century later, according to an Inscription on Face 2 at Wat Pa Mamuang (Phasa Khmer) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021c), another Buddhism-supporting king, Li Thai (r. 1347–1368), established relations with Sri Lanka by summoning the *Tripitaka* and sending monks to study there. He also began the new calendar system with the end of the year in the fourth lunar month, thus the beginning of the year was the first Waxing Moon day of the fifth month in 1361. According to his *Triphumitaka* book, the old Sukhothai Kingdom's calendar was the *Mahasakaraj* with a Full Moon ending system (*Purnimanta*). This could imply that he switched from the *Mahasakaraj* to the *Culasakaraj* Calendar.

Later, the Buddhist *Nirvāṇa* Era, which declared that the elapsed Buddhist years counted from the Buddha's decade date, was recorded on several inscriptions in both the Sukhothai and Lanna Kingdoms. The earliest inscription in Sukhothai was found at Than Phra Phuttharup Pha Khao Thong and was scripted in 1422 (elapsed 1965 years, 5 months, and 22 days) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2022), while the earliest Lanna inscription, found on Face III at Kasat Ratchawong Mang Rai, was scripted in 1411 (elapsed 1954 years, 5 months, and 14 days) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021b). The latter date appears to have gained acceptance after the reign of King Kuena (the 6th Mangrai Dynasty, Lanna Kingdom; r. 1367–1388), i.e., around the year 1400.

One of the Buddhist Pali manuscripts in Lanna is the *Shinkalmalipakorn*, which was written in 1516 by Rattanapanya Thera, a *Sangharaja* (*Thai*: สังฆราช, chief of *Sangha*) during King Muang Kaew's reign (1495–1525). This manuscript was employed during the Buddhist *Nirvara* Era and was used by Sri Lankan Theravada Buddhists.

1.2 Characteristics of the Lanna Calendar

Early Lanna's use of timekeeping, as evidenced by records such as the Wat Chiang Man Inscription (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021e), is unique and is referred to here as the 'Lanna Calendar', which is a lunisolar calendar with various elements added, i.e., the Moon's *Tithi* (*Thai*: ดิถี; lunar day) and *Rœk* (*Thai*: ฤกษ์; lunar mansion), the day and year's names following the *Hon Tai* system (*Thai*: ระบบหนไท)—similar to the Chinese 'ganzhi' or the sexagenary cycle, which is a cycle of sixty terms numbering days and years—and a weekday. Later Theravada (Lankavamsa) and relics were distributed from Sukhothai during King Kuena's reign, and Lanna time reckoning always included the Buddhist *Nirvāṇa* Era.

The same as the Burmese Calendar, the Lanna Calendar is the *Culasakaraj* (CS) which is largely based on the Hindu Calendar, an older version of the *Surya Siddhanta* calculated with the arithmetical (not astronomical) positions of the Sun and the Moon. A year in the CS (and *Hon Tai* year) has a solar sidereal year length of 365.25875 days, with the year beginning when the Sun enters the starting point of *Meṣa Rāśi* (Aries) on that day, so-called '*Phayawan*' (meaning 'the Great Day'; for the Thais known as '*Thaloeng Sok*').

The position of the Sun and the five classical planets are placed in the 12 *Rāśi*s (Hindu zodiac signs), while the Moon is housed in 27 *Nakṣhatra*s (lunar mansions; in Thai and Lanna called '*Rœk*'). The names of the lunar months are defined according to where the Full Moon is, e.g., the *Vishākhā* month (the eighth Lanna lunar month, equivalenced to the sixth Thai lunar month) when the Full Moon is in the *Vishākhā Nakṣhatra* or *Rœk* 16 (see Figure 1). This Full Moon day, which currently in Thailand is called *Visakha Bucha* Day (also known as *Vesak*), is the most important Buddhist festival commemorating Gautama's birth, enlightenment and death (*Nirvāṇa*).

The Lanna Calendar has two different ways of counting days in order to determine New Year:

(1) the solar year, as mentioned above, is actually the solar sidereal year, i.e., the Hon Tai year and the CS, counting from *Phayawan* Day that currently falls in April; and
(2) the lunar year, i.e., the Buddhist *Nirvāṇa* Era, counting from *Visakha Bucha* Day (now around May) as the start of the Buddhist year elapsed. The lunar year in the Lanna Calendar is divided into three types: a regular year with 354 days, an *Adhikavara* (leap-day) year with 355 days, and an *Adhikamas* (leap-month) year with 384 days.

Furthermore, it is common to construct Viharas on *Visakha Bucha* Day, which is consider-

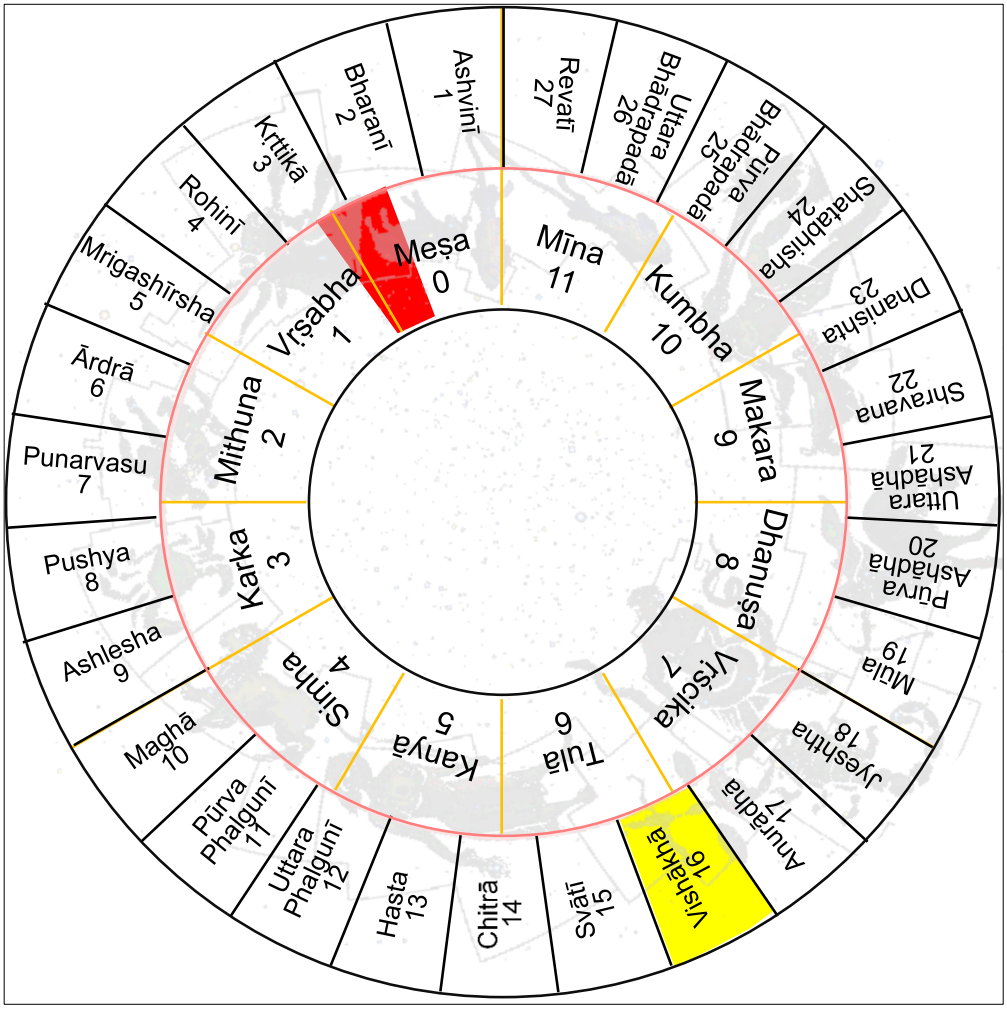

Figure 1: The Hindu names of the 12 *Rāśi* and 27 *Nakṣhatra.* The highlight colours indicate on *Visakha Bucha* Day that the Full Moon is in the *Vishākhā Nakṣhatra* (shaded in yellow), whereas the Sun should pass by Meṣa to *Vṛṣabha Rāśi* (shaded in red) (background image: modified from a star map generated using Stellarium 0.21.3).

sidered an auspicious da (for example, Wat Phan On Vihara, Wat Bupparam Vihara, Wat Dok Kham Vihara, and Wat Chiang Yuen Vihara; all in present-day Chiang Mai). Buddha statues were created on such a day, for example, Than Phra Phuttharup Wat Chiang Man Inscription (AD 1465) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021g), Than Phra Phuttharup Wat Phra Sing (Phra Chao Thong Thip) Inscription (AD 1477) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021d), Chao Muen Lo Mongkhon Inscription (AD 1501) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2021f), and Kan Patisangkhon Phra Maha Chin That Chao Lam Pang Inscription (AD 1957) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2020). Most of these were inscribed on *Visakha Bucha* Day with the year expressed in both the Culasakaraj and the Buddhist *Nirvāṇa* Era as well as the Hon Tai year.

The *Visakha Bucha* Day was used as the starting date of the Buddhist *Nirvāṇa* Era, a traditional Buddhist calendar in Thailand until when it changed to the *Putthasakaraj* (*Thai*: พุทธศักราช; Buddhist Era, BE), which started on 1 April 1913 (2456 BE) and presently the *Putthasakaraj*, which started on 1 January 1941 (2483 BE), and contains both the Gregorian and Thai Lunar Calendars.

1.3 Astronomical Description of the *Vishākhā Nakṣhatra*

In Indian astrology, the *Vishākhā Nakṣhatra* governs arithmetically from 20° *Tulā* to 3° 20′ *Vṛścika* as highlighted in yellow color in Figure 1. In an astronomical sense, however, the associated star for the *Vishākhā Nakṣhatra* varies across cultures, religious beliefs, and periods, and is a star that is in the relevant *Nakṣhatra* but may not be a prominent naked eye star.

Figures 2, 3 and 4 show astrological charts that contain stars representing the *Rāśis* and *Nakṣhatras*, which were known to Lanna astronomers. Fascinatingly, we found that these ancient charts have three different asterisms that denote the *Vishākhā Nakṣhatra or Rœk* 16, as discussed in detail below.

The first (Type I) is from Wisandarunkorn's *Suriyayatra* Text, on which the calculation of the current Thai Lunar calendar is based, and it declares the *Vishākhā Nakṣhatra* to be Corona Borealis (Wisandarunkorn, 1997: 259) and depicts the represented stars as shown in Figure 2a. Another relevant record is the Tai Yai, which was found at Wat Ban Saen in Kengtung (currently a town in Shan State, Myanmar). This was written in the Tham Khün script as a *Pabsa* (a palm-leaf manuscript and local paper-book made of the tree-pulp), and it states that the *Vishākhā Nakṣhatra* is the 'Kob Dong Star' (*Thai*: 'ดาวขอบดัง'; which means 'a threshing basket rim star') (Injan, 2021: 30), as illustrated in the painted ceiling (Figure 2b) at the Kyauk-tawgyi Pagoda (built in 1847) in Amarapura, Burma (Ôhashi and Orchiston, 2021: 691–705). Both asterism drawings for the *Vishākhā Nakṣhatra* are unlikely to be the constellation Libra, which is used in India (Saha and Lahiri, 1992: 46), and the 5-to-8-star configuration appears curled like a crown-shaped pattern, suggesting that it depicts the constellation Corona Borealis (CrB), which consists of seven stars. Note that both pieces of evidence

(1) are portrayed as being only a few hundred years old, although they are assumed to be primarily imitative of an earlier source; and
(2) were not found in Lanna, but there are some significant links between Lanna and Burma, e.g.

(a) the belief in building Buddha Relics stupas on the tops of the hill is from Mon or Burmese culture that Sumana Thera (who studied and was ordained in the Lankavamsa Monastery at Hpa An, Myanmar) brought to Lanna (Damrikul, 2017);
(b) the Thai *Culasakaraj* and the Lanna Calendars were derived from the Burmese Calendar (Gislén and Eade, 2019);
(c) Kengtung was founded by King Mangrai (Lanna Kingdom founder; r. 1296–1311) in 1267 and was a tributary state of Lanna until the reign of Kuena (Ongsakun et al., 2005: 99–100); and
(d) Lanna was ruled by the Burmese from 1558 to 1774 (Ongsakun et al., 2005: 109–128).

For the second type (Type II), the *Vishākhā Nakṣhatra* is represented by several stars with a straight-line pattern, for example, four stars (Injan, 2021: 90) on the astrological chart shown in Figure 3a and five stars (Tumtong, 2017) on the chart shown in Figure 3b. Similar Lanna astronomical charts of Type II were also found in temples in Phrae and Lamphun provinces (Injan, 2021: 91–92). All the charts were labelled in Tham Lanna script, and each *Nakṣhatra* had the same basic pattern but was depicted differently. In addition, the Tai text *Pabsa* written in the Tham Lue script and found at Wat Ban Luk in Lamphun states that this *Nakṣhatra* is a snake star (Injan, 2021: 26). From all the evidence, the *Vishākhā Nakṣhatra* (*Rœk* 16) seems to be the three stars β, δ and π Scorpio, adjacent to Libra, which appear in a line and can have the other two stars on either end (ν and ρ Scorpio), even though as with Type I, such stars normally represent the *Anurādhā Nakṣhatra* (*Rœk* 17). At the present-day, all five stars have a southern declination between 20° and 30°, and when they rise on the horizon they have a southward tilt from the east.

In the third type (Type III) which is common in Hindu astrology, the *Viśākhā Nakṣhatra* is represented by four stars in Libra, comprising α, β, γ, and ι Librae, in the southern celestial sphere. The 6-star pattern illustrated in Figure 4a and the 4-star pattern in Figure 4b, both have square-like patterns similar to the four stars in Libra that are regarded as the *Viśākhā Nakṣhatra.* In summary, the orientation of the Phra That Doi Suthep Temple is oriented north of east, so Type I, represented by CrB, which is in the northern celestial sphere and rising east to north, is more likely to be taken into consideration in this study than Type II and Type III, whose associated stars are rising east to south.

1.4 The Construction Timeline for the Phra That Doi Suthep Temple

Since King Kuena established the tradition of choosing a Sangha chief to manage the monastic community's governance, the Lanna people were believed to have adapted to Theravada Buddhism under his patronage. With Buddhist teachings and relics brought from Sri Lanka, the monks returned to their home countries and began building monasteries and stupas. The Sinhalese Theravada Mahavihara tradition was most likely influenced by the Lanna or, more specifically, the Phra That Doi Suthep Temple. When the king enticed Sumana

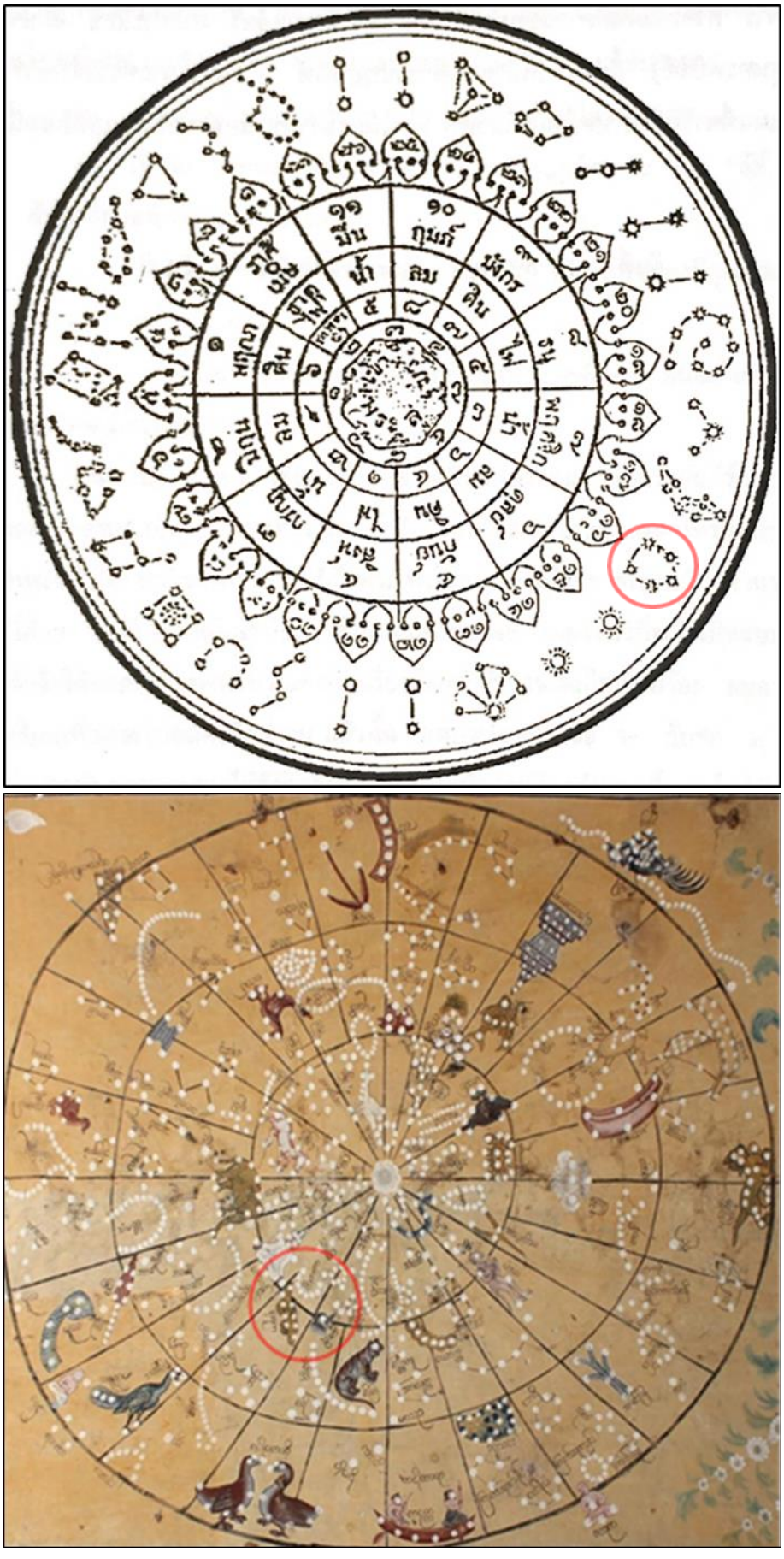

Figure 2: The associated asterism for the Vishākhā Nakṣhatra is Corona Borealis (Type I), which is represented in Figure 2a (top), an astrological chart in the Suriyayatra Text (after Wisandarunkorn, 1997: 208) and in Figure 2b (bottom) on the Burmese zodiac painted on the ceiling at the Kyauktawgyi Pagoda in Amarapura in Myanmar (photograph: Saknarin Chaongiw). The red circles indicate the *Vishākhā Nakṣhatra*.

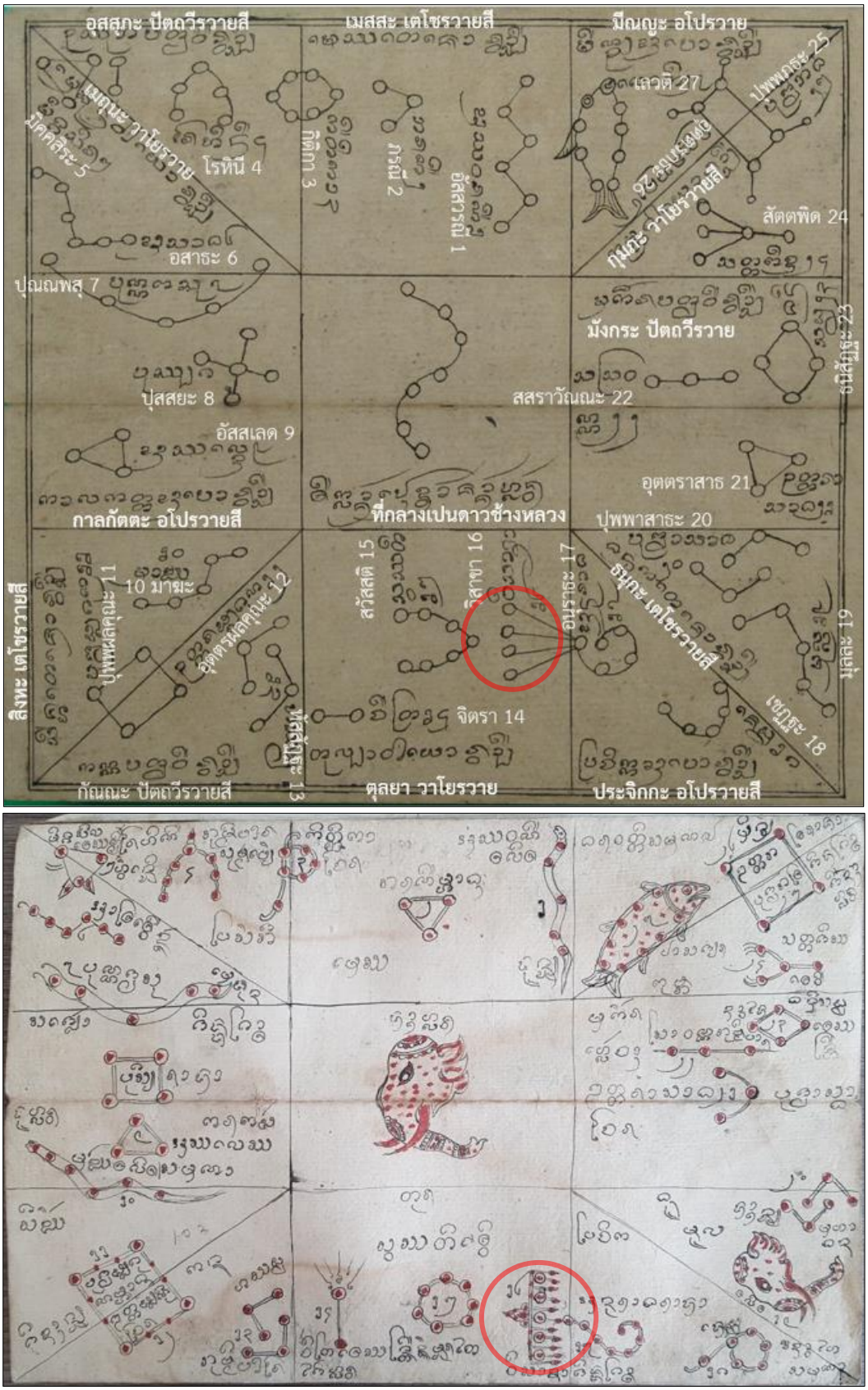

Figure 3: The associated stars for the *Vishākhā Nakṣhatra* seem to be the three stars β, δ and π Scorpio that are adjacent to Libra (Type II), and represented in Lanna astrological charts in the Pubsa as in Figure 3a (top, after Injan, 2021: 90) and Figure 3b (bottom, after Tumtong, 2017). The red circles indicate the *Vishākhā Nakṣhatra*.

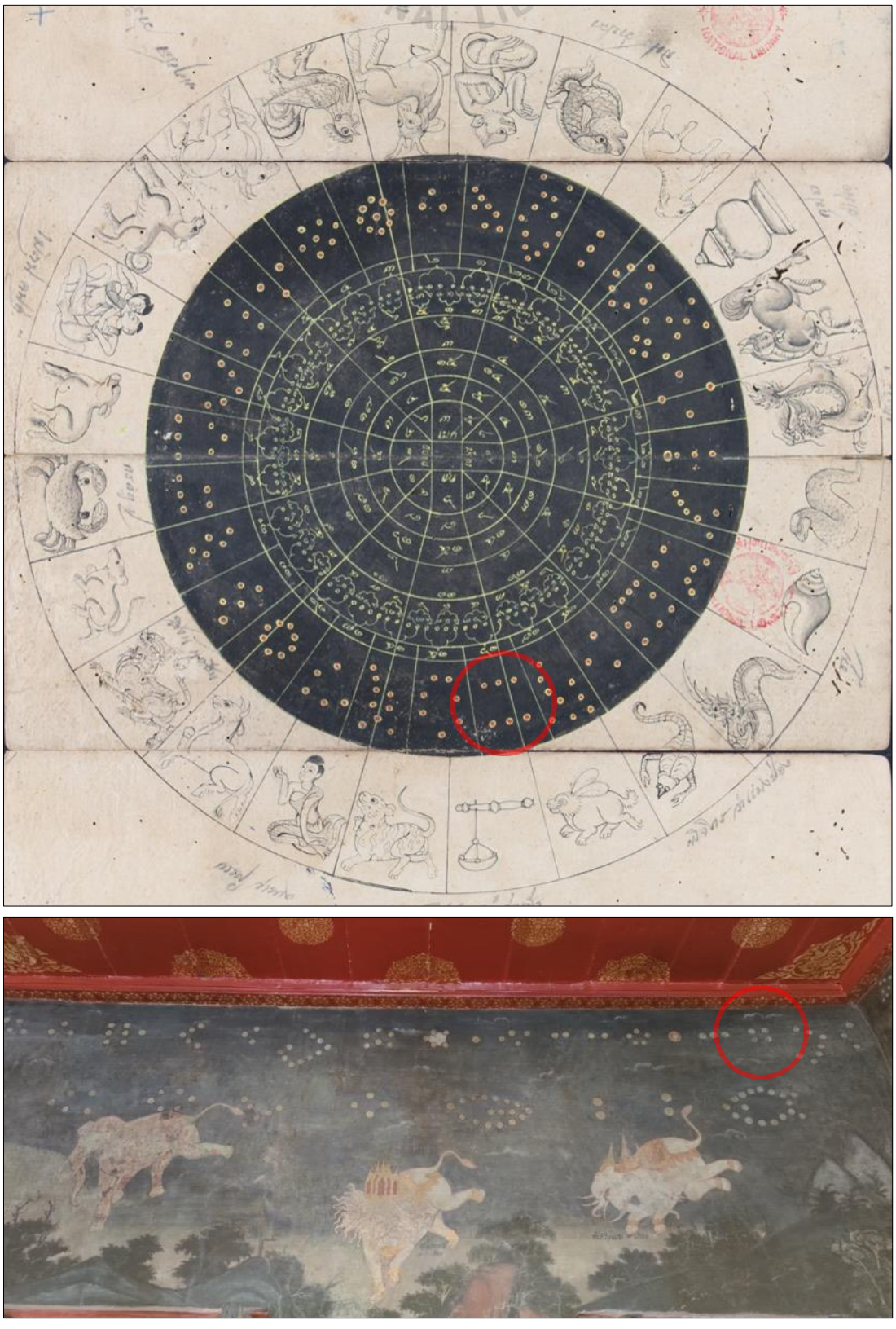

Figure 4: The associated star for the *Vishākhā Nakṣhatra* is four stars in Libra (Type III) represented in Figure 4a (top) by an astrological chart drawing in the 'Khumpee Dao', collection no. 27, kept in the National Library of Thailand (after Sangdee, 2019) and in Figure 4b (bottom) by a painting on the west inside-wall of Hor Tri Wasukri, Wat Phra Chetupon Wimon Mangklaram (photograph: Worapon Maison). Both are from the Early Rattanakosin Period (1782–1851). The red circles indicate the *Vishākhā Nakṣhatra*.

Thera from Sri Satchanalai (presently in Sukhothai Province, Thailand) to start a mission for Theravada Buddhists in Lanna, he also brought the relics of Lord Buddha to Chiang Mai. The relics were enshrined in a stupa, which is located at the top of Doi Aoy Chang (now Doi Suthep, a mountain to the west of Chiang Mai and overlooking the city), like the Great Stupa at Sanchi in India.

Later, in the mid-fourteenth century, the Phra That Doi Suthep Temple was established. The temple records list three different construction dates for King Kuena stupa: the earliest is AD 1371; the second is 746 CS, on the Full Moon day of *Vishākhā*, Friday, and *Rœk* 16 (*Vishākhā Nakṣhatra*), *Hon Thai* day named '*Ka Med*' (the Day of the Goat) (Fine Arts Department, 2515: 1–10), equivalent to Friday 14 May 1384 (Gregorian); and the third is 748 CS on the Full Moon day of *Vishākhā*, Wednesday, *Rœk* 16 named *Vishākhā*, *Hon Thai* year named '*Kap Jai*' (the Year of the Rat), which has no equivalent date in the year 1386. The third date is likely to contain false information, in that 748 CS was not the Year of the Rat but rather the Year of the Tiger. We believe that the second date, 746 CS, is the most accurate.

Next, King Mueangketklao (the twelfth and fourteenth Mangrai Dynasties; r. 1526–1538 and 1543–1545, respectively) requested Phra Mahayana Mongkol Pha of Wat Asokaram (Wat Romneeyaram) in Lamphun (presently a province in Northern Thailand) to erect a higher and wider stupa (see No.1 in Figure 5a), which can still be seen to this day. It was built on the thirteenth Waxing Moon day of the eighth Lanna (*Vishākhā*) month in 900 CS, *Rœk* 12 (*Uttara Phalgunī Nakṣhatra*), *Hon Thai* year of '*Berk Sed*' (the Year of the Dog), equivalent to the Gregorian date of Thursday 21 April 1538, with the auspicious time set at 8:24 a.m.

Subsequently, in 905 CS, *Hon Thai* year of '*Ka Mao*' (the Year of the Rabbit), equivalent to AD 1543–1544, this chief monk continued to build the east Phra Brihat Vihara (No.3) and the west Phra Budh Vihara (No.2), along with Vihara Kod (cloister; No.6) and Ubosot (No.7) around the stupa. King Tao Saikham (from the thirteenth Mangrai Dynasty; r. 1538–1543) presented the gold to be beaten into sheets called *jango* to cover the stupa, and his Royal Family contributed funds to construct the east and west viharas (Bandit Chao Nakorn Chiang Mai, 1990: 14–15). Phrajao Tanjai Vihara (No.4) and Phrajao Un-Muang Vihara (No.5) were built by King Kawila (the first King of the Choa Chet Ton Dynasty; r. 1782–1816) in 1803 and 1806, respectively.

1.5 Lanna Temple Orientation: A Review of Previous Studies

In ancient times, monk/astrologers who specialized in using astronomical events in astrological predictions and seasonal forecasting were in charge of observing celestial occurrences from the temple and were expected to advise their king and people on dates, festivals, and seasons (particularly for cultivating). They were experts at using the positions and the rising and setting times of stars that were mostly in zodiacal constellations (the twelve *Rāśi*s for each month and the 27 *Nakṣhatras* for each day), and determining the positions of the Sun and Moon with respect to these background stars in order to set up agricultural calendars. Consequently, most astronomical records and inscriptions that exist today have been discovered in Thai temples (i.e. Wat).

In the early days of constructing Lanna temples the Vihara of Wat Phra Yuen in Lamphun served as an astronomical reference with criteria for checking the Full Moon and the New Moon to indicate an intercalary day/month in calendar-making (Yodintra, 2007). For many decades Yodintra et al. (2011) studied temple orientations in Lanna and its related kingdoms and they suggested that the orientation of each local temple was associated with the rice farming variety and activities that coincided with the seasons, from which the calendar was developed by observing from the temple aligning to the rising Sun's specific angles of 23.5°, 17.625°, and 11.75° from due east.

Besides, it was found that some sacred sites in the Early Lanna Period were aligned to a somewhat different angle, while most temples from the Late Lanna Period were aligned due east. These variations in orientation were presumed, like the orientation Prasat Hin Phanom Rung (Komonjinda et al., 2019) to be linked to the directional azimuths of specific stars, such as Spica, the Pleiades, etc., which gradually changed due to the precession of the Equinox. To summarize, the orientation of a Lanna temple may be aligned not only in relation to the Sun but also to a specific star at twilight.

Apart from religious sites, Saelee et al. (2021) also examined the planning of Chiang Mai city and suggested that the plan might be designed based on the *Vaastu Shastra* principle, an ancient Indian science of architecture known as *Vaastu Shastra* that is a part of the *Vedanga* of *Sthapatya Veda* in *Atharva Veda*, as written in Varāhamihira (ca. 505–587)'s textbook, *Brihat Samhita* (Kramrisch, 1976: 10–11;

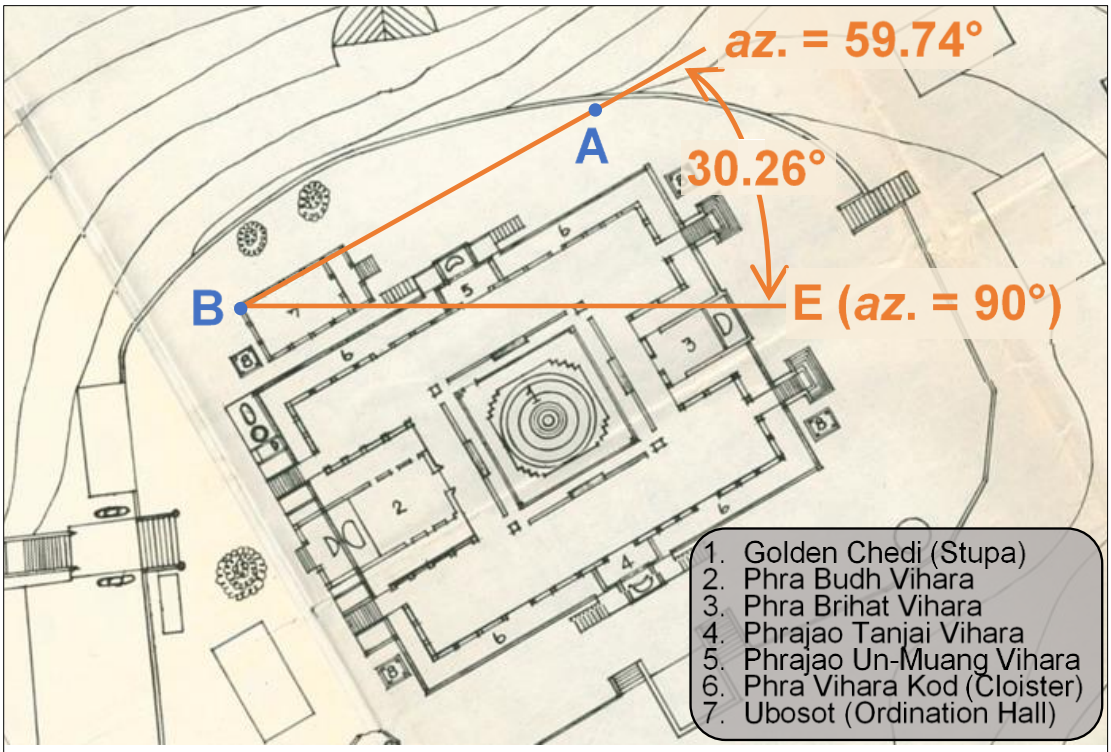

Figure 5a (top): The plan of the Phra That Doi Suthep Temple (modified from Fine Arts Department: Fine Arts Department, 2515). Figure 5b (bottom) shows a satellite image of the temple (image: © OpenStreetMap contributors).

Sastri and Bhat, 1946). King Mangrai, the Chiang Mai city founder, selected an auspicious site with seven good omens for the site, for example, Suthep Mountain to the west, the Ping River to the east, a water reservoir to the northeast, and fertile soil for farming, for his new capital city. He also chose an auspicious date and time to begin construction, according to astrological calculations based on the positions of the Sun, the Moon and the five classical planets. Such a date was on *Phayawan* Day, the CS New Year's Day, and Komonjinda et al. (2019) suggest that Spica might have been used to indicate that day.

According to the *Vastu Purusha Mandala*, every temple construction must begin by selecting a star or asterism that promotes the positive side. For example, the alignment of an ancient Lanna temple might be linked to Spica at the time when it was built, to commemorate the *Phayawan* Day in the Lanna Calendar. In the case of Phra That Doi Suthep Temple, it was assumed that the orientation of this temple was aligned to the asterism Corona Borealis on the day of the stupa's founding, which also was the *Visakha Bucha* Day.

2 METHODS

For this study, two datasets necessary to examine the orientation of Phra That Doi Suthep Temple in relation to the rising/setting of Corona Borealis on *Visakha Bucha* Day were acquired: (1) measurement of the temple's orientation; and (2) determination of the position and the rising and setting times of Corona Borealis. *Stellarium* (version 0.21.3, with ΔT correction using the default Espenak and Meeus (2006) model, accounted for atmospheric refraction and extinction, and a proper motion) was used to calculate the astronomical coordinates of celestial objects in the ancient sky.

2.1 Measurement of Orientation

The temple's orientation was surveyed with a Topcon, GTS-100N theodolite/total station. This theodolite is a precision optical instrument for measuring angles between designated visible points in the horizontal and vertical planes. In a non-transit theodolite, the telescope cannot turn about the vertical plane through the zenith and vertical rotation is restricted to a limited arc (~30°). In this study, a methodology was developed to evaluate the azimuth of the temple orientation very precisely in relation to Polaris (if possible) and some bright stars whose altitudes were <30° at the time when the measurements were made. The procedure was as follows:

(1) select the baseline at the temple which was to be investigated;
(2) set the theodolite at one end of the baseline, and mark it as the zero horizontal position;
(3) measure the horizontal and vertical positions of the selected star over time; and
(4) calibrate the measured positions using the calculated azimuth of the star, and determine the orientation of the temple. A portable GPS (Garmin, eTrex® 32x) also was used to obtain the location of the theodolite and its altitude above mean sea level, both of which were used to specify the observed location in the *Stellarium* software.

2.2 Determination of the Date and Position of Corona Borealis

Star alignments have a remarkably specific relation to the seasons, and this relationship changes very slowly with time as mentioned earlier. This correlation of heliacal, acronychal and cosmical rising/setting of some identified stars (or constellations) with the tropical seasons also changes over time. In our case, the positions at the rising and setting of Alphecca (α CrB)—the brightest star in the constellation with a magnitude of 2.2 as a representative of the *Vishākhā Nakṣhatra*—were calculated using *Stellarium*. The behavior of Alphecca's rising and setting times during the tropical (seasonal) year was generated for the year 2022. Similarly, the times for sunrise and sunset were obtained from the ESRL's Global Monitoring Laboratory (GML) of the National Oceanic and Atmospheric Administration (NOAA) (see https://gml.noaa.gov/grad/solcalc/table.php?lat=18.80526&lon=98.92165&year=2022), and the times of civil twilight, nautical twilight and astronomical twilight were obtained from the Time and Date AS's website (https://www.timeanddate.com/sun/thailand/chiang-mai?year=2022). As a result, heliacal, acronychal and cosmical rising and setting times were obtained. Finally, the yearly variation of the Alphecca's azimuth at acronychal rising due to precession also was examined.

3 RESULTS AND DISCUSSION

3.1 The Orientation of Phra That Doi Suthep Temple

This study aimed to measure the stupa's axis since this building was expected to be the oldest one at the temple. However, when measuring directly from the inside of the wall, we were unable to drag a long enough baseline. This would result in significant discrepancies on four sides of the structure, with a tree line obscuring the north. As a result, measurement

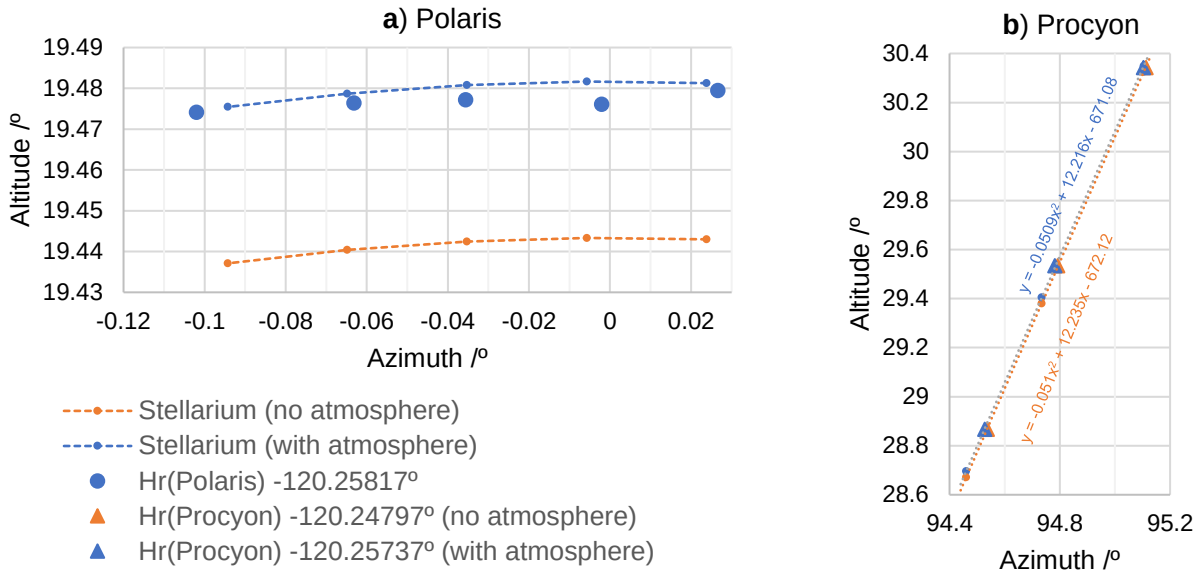

Figure 6: Measured horizontal positions (*Hr*) from the theodolite were calibrated to the azimuth (horizontal coordinate) of a) Polaris and b) Procyon obtained from the *Stellarium* software. The dotted lines are linear regressions. The color indicates consideration of atmospheric refraction (diagram: the authors).

point A (see Figure 5a), in front of the Ubosot with a wide space at the front side of the mountain and facing to the north and east was chosen as a 'baseline', paralleling the axis of the stupa.

The measurement was done by setting the theodolite at point A and extending the baseline to point B at the Ubosot, 40.9 m away (see Figure 5a), setting the horizontal position (*Hr*) to 0° for reference, and then collecting the horizontal and vertical positions of Polaris and Procyon over time. All collected positional data were shifted by adding an 'offset' value to match the azimuth and altitude of both stars obtained from *Stellarium*. This is illustrated in Figure 6. The 'offset' value was determined using the least-squares approach, by minimizing the sum of the squared residuals (a residual being the difference between an observed value and the fitted value provided by a model).

The calibration analysis for Polaris and Procyon differed because Polaris' apparent motion around the North Celestial Pole is so small that the altitude remains unchanged during transit, whereas Procyon rises with altitude increasing to almost 1° while the azimuth increases by just 0.3° in three-minute intervals. The consistency of air pressure and temperature throughout data collection was critical to the issue of refraction. When comparing the star coordinates at Phra That Doi Suthep Temple (18.80526° N, 98.92165° E) calculated using *Stellarium*, atmospheric pressure, temperature, and the extinction coefficient were set to 89157.4 Pa, 30°C, and 0.20, respectively, where the pressure was calculated for the temple's1066 m height above mean sea level.

In Figure 6a atmospheric refraction does not affect the azimuth of Polaris, but it does affect the altitude (the difference is about 0.04°, or less with zero refraction). All observed altitudes are nearly equal with a deviation of less than 30 arc-second (0.00833…°), therefore the calibration procedure was only performed on the azimuth. It was found that the offset value, or angle between the baseline and the North Celestial Pole line on the horizontal plane, was 120.258°, resulting in the Ubosot axis facing 59.742° azimuth. For the calibration of Procyon's data displayed in Figure 6b, the least-square approach was applied to the altitude fitting using the quadratic equation accounting for refraction, and yielded offset values of 120.257°, and 120.248° without refraction. In summary, the mean azimuth of the Ubosot axis was 59.742 ± 0.005°.

One of these issues may cause discrepancies in the axial measurement of Phra That Doi Suthep Temple resulting in the analyzed offset value. The theodolite has a device resolution of 1 arc-second (0.0002877…°), but the resolution of the calibrated result (the mean azimuth is 59.742 ± 0.005°) reaches the third decimal place. In fact, some discrepancies can be caused by drawing the baseline, for example, from the baseline length of 40.98 m, if the expected error from the endpoint B is 1 cm, the error is 0.014° = $\tan^{-1}$(1cm/40.98m). This indicates that the Phra That Doi Suthep Temple is oriented with an azimuth of 59.74 ± 0.07°, or 30.26 ± 0.07° north of east.

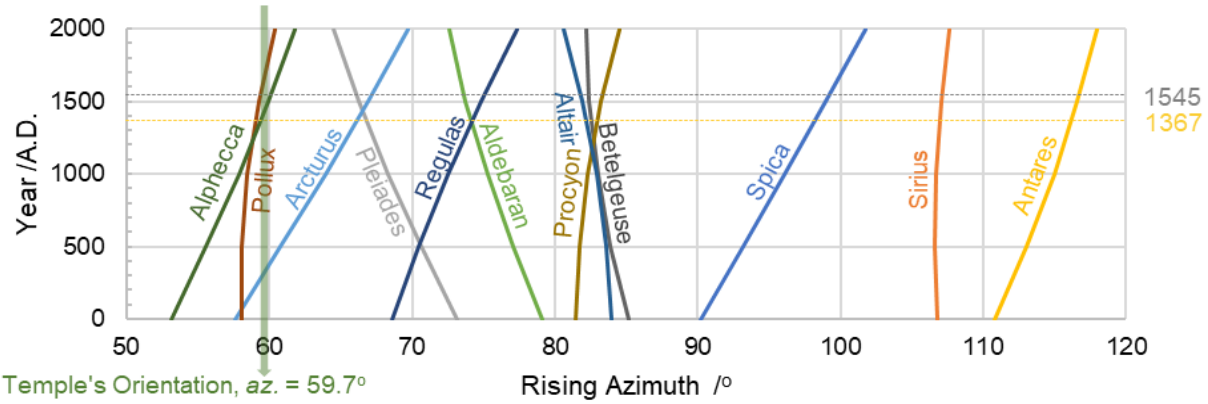

Figure 7: This plot shows the changing azimuths of prominent stars seen rising on the eastern horizon (zero altitude) from Doi Suthep Temple over two millennia due to the precession of the equinoxes (plot: the authors).

Another issue, as seen in Figure 5b, is that the building structure appears to be asymmetrical, with the wall of the south Phra Vihara Kod (Cloister) more inclined than the north one, but this was not considered in our study.

3.2 The Position of Corona Borealis

All the Corona Borealis positional observations related solely to Alphecca (α CrB). At apparent visual magnitude 2.2 it was by far the brightest star in the constellation, the other six naked eye stars all being about 4th-magnitude. Although Alphecca is not a bright star on the eastern horizon at dusk, in 2022 it was observed rising at az. = 62° by noticing Arcturus (az. = 74°, alt. = 15°; rising 67 minutes earlier) and Spica (*az*. = 108 °, alt. = 17°; rising 74 minutes earlier). While CrB ascends from the horizon, it has a 4° boundary, with Alphecca's azimuth close to the east. Calculation of the positions of the Sun, Moon and stars in the sky was based on reliable and accurate modern knowledge.

The astronomical calculation of Alphecca as a representative of the Corona Borealis constellation was implemented in *Stellarium* 0.21.3 using the procedure described in Section 2.2. The analysis was conducted as follows: firstly, understanding the overall position of CrB on the ecliptic, and how it is related to other bright stars and affected by the precession of the equinox; secondly, exploring a skyscape when the rising and setting of CrB changes day by day; and finally, tracking back in time to uncover when CrB's azimuth was associated with the temple's orientation.

3.2.1 The Effect of Precession

When the First Point of Aries was introduced by Hipparchus (ca. 190–120 B.C.), he measured the longitude of Spica, Regulus and other bright stars and concluded that Spica had moved 2° relative to the autumnal equinox. He also compared the lengths of the tropical year and the sidereal year and found a slight discrepancy. He concluded that the equinoxes were moving ('precessing') through the zodiac, and that the rate of precession was not less than 1° in a century (which is close to the actual value of 1.38°; see Saha and Lahiri, 1992: 200).

As illustrated in Figure 7, the azimuth of the stars change over time according to the *Stellarium* computation, which takes the effect of precession into account. The rising azimuth of various stars, including Alphecca, at Wat Phra That Doi Suthep as a function of time is plotted. In 2022 the azimuth of α CrB was 62°, but about 500 years ago its azimuth appeared to be closest to that of the temple. Analogous to the rising azimuth, the setting azimuth has the same pattern that can be represented by simply substituting '360 – setting azimuth' for the rising azimuth axis.

Figure 8 shows Spica's ecliptic longitude on a star map. Spica was located nearly 180° opposite the First Point of Aries in 140 BC, but exactly opposite the vernal equinox in 285 (marked by a blue line). Going back to around 1000 BC, which was during the Vedic period (ca. 1500–500 BC), the vernal equinox might be noticed with CrB, at an ecliptic longitude of 223°, as marked by the yellow line. Moreover, the Vedic literature, indicates that the Vedas (ca. 1300–900 BC) used two stars in Taurus, perhaps Aldebaran (now with an azimuth of 70.1°) and the Pleiades (now with an azimuth of 60.0°), to mark an auspicious beginning time. However, when looking at the green line in Figure 8, we see that this was the vernal equinox around 3000 BC, during the Indus Valley Culture (also known as the Harappan Civilization of ca. 3300–1300 BC), when Aldebaran was located at 180°, exactly opposite Antares (which now has an azimuth of 250.1°).

The ecliptic longitudes calculated by the

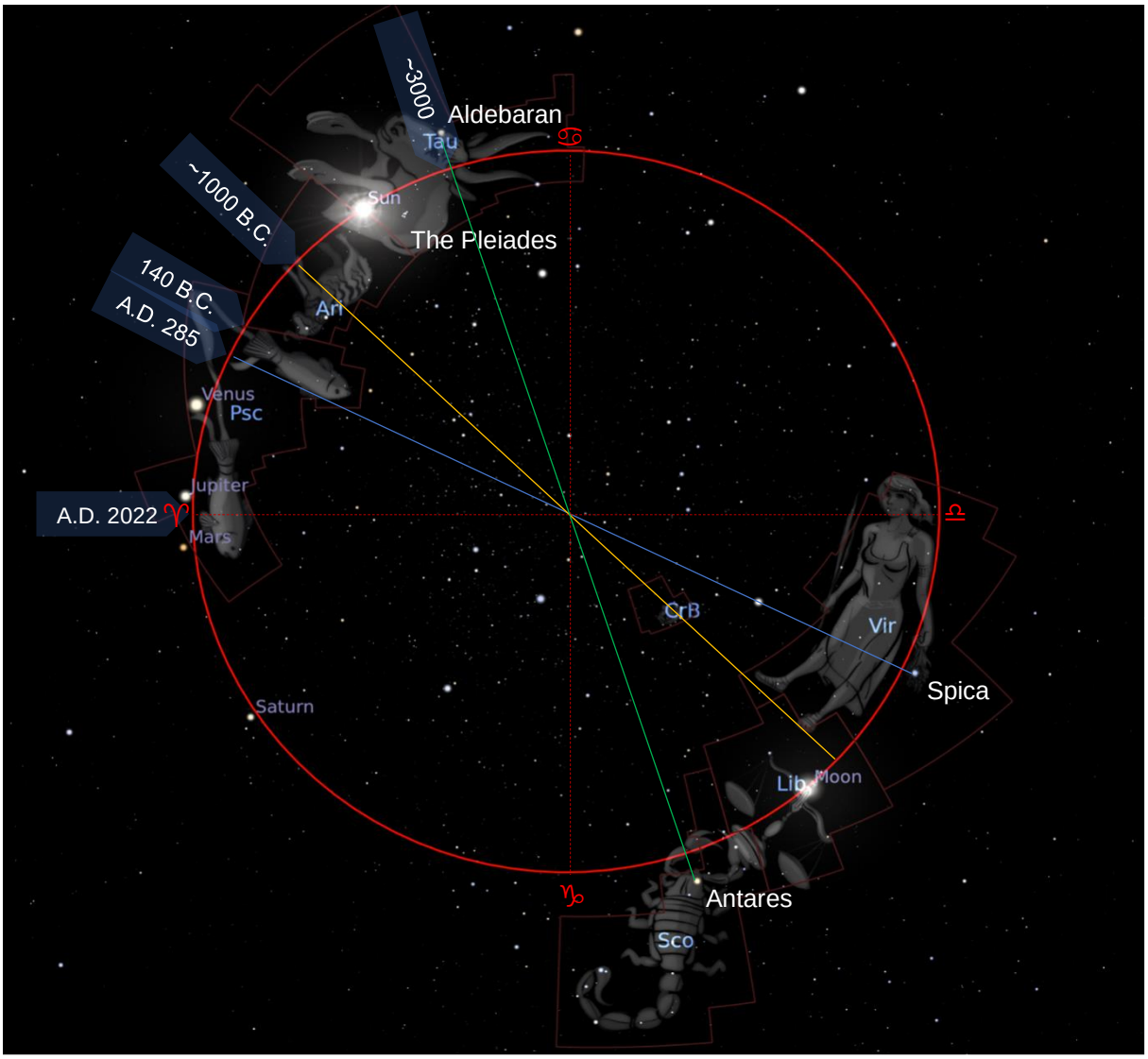

Figure 8: This star map displays the ecliptic longitudes of Spica and Antares in relation to the current vernal equinoctial point (♈) where it is zero longitude (AD 2022). The equinoctial point shifts anticlockwise from Taurus in the past (the Indus Civilization ~3000 BC) to Pisces at present. The Full Moon on *Visakha Bucha* Day (15 May 2022) is near the constellation of Corona Borealis at the longitude marked by a yellow line and clearly opposite the Sun (image: modified by the authors from a star map generated by *Stellarium* 0.21.3).

Stellarium software for Spica in 140 BC and AD 2022 are 174.1° and 204.1° respectively, whereas CrB's longitudes are 192.2° and 222.6°. Note that because the precessional cycle is approximately 26,000 years long, or 1° every 72 years, both ecliptic longitudes shifted by about 30° between 140 BC and AD 2022.

According to Komonjinda et al. (2019), the bright star Spica may be used to identify the starting point of *Meṣa Rāśi*—equivalent to the First Point of Aries—to indicate the New Year's Day of the *Culasakaraj* Calendar. Spica was exactly on the autumnal equinoctial point opposite the vernal one in AD 285. The Saka epoch (AD 78) and the *Culasakaraj* epoch (AD 638) were both in this period when Spica could have been used to mark the beginning of the year when the Sun crossed the *Meṣa Rāśi* starting point. On the other hand, the Buddhist *Nirvāṇa* epoch was earlier than both, and it might have been based the calculation system in the *Vedanga Jyotisa*, in which the Pleiades was the designated star on the vernal equinoctial point, and either Libra or CrB were on the opposite one. The early Buddhists employed the ancient Vedic Calendar, which was later replaced by the Vikrami Calendar (epoch 57 BC), which is still extensively used in Northern India. In the case of the Vikrama Era which is used in parts of Guzrat, the year begins in *Kṛttikā* (the Pleiades), resulting in the first month of the solar year being *Vishākhā* month (Saha and La-

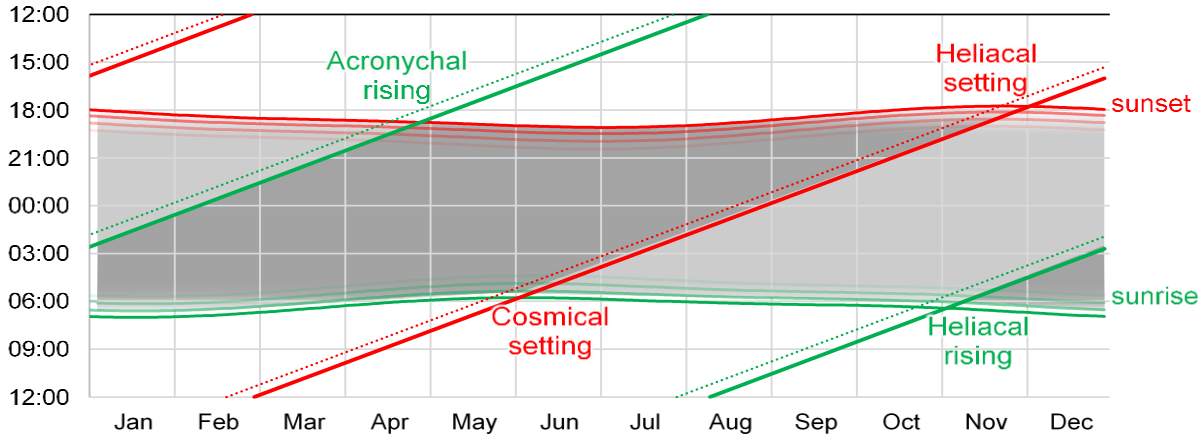

Figure 9: Rising and setting times of Corona Borealis at Phra That Doi Suthep Temple (GMT+7) throughout the year 2022 (solid line) and in 1500 (dotted line). The green and red colors represented rising and setting, respectively. Corona Borealis is only visible (dark shaded area) in the night-time (gray shaded area). Civil, nautical, and astronomical twilight times are also included (diagram: the authors).

hiri, 1992: 241, 254–258). Like Sri Lanka's Buddhist *Nirvāṇa* Era, the year begins on the Full Moon of the *Vishākhā* month.

3.2.2 Rising and Setting with Sunrise/Sunset

The shifting in ecliptic longitude coordinates in the equatorial system and the alt-azimuth system occur gradually over time. From the observer's viewpoint, stars will rise and set earlier each day because a sidereal day is shorter than a mean solar day by about four minutes.

The times of CrB rising and setting at Phra That Doi Suthep Temple were inspected for the year 2022, as illustrated in Figure 9. Due to the precession of the equinox, such times in the year 1500 were shifted about one-third of a month earlier, as plotted in dotted lines. But during the years 1500 to 2022 the equinox point also shifted by about one-quarter of a zodiac sign. The difference was thought to be caused by the nonlinear relationship. The diagram also includes the times of sunrise and sunset, with night-time indicated by the light shaded area, to display the time during which CrB could have been seen (dark shaded) each day.

In ancient times, the rising and setting of the stars related to the Sun, at or close to sunrise and sunset. In this 'astronomical' sense, there are four different risings and settings, each of which occurs just once a year. The four events must be inferred instead of observed, and the dates can only be determined by calculation. These phenomena cannot be observed because the star is obscured by sunlight and these occurrences are not visible.

The CrB and Sun lines intersect at four points, which are known as:

- 'Acronychal rising'—CrB crosses the eastern horizon as the Sun crosses the western horizon. This is the last day (2 May) when CrB (after a period when it had been visible at night) rises in the evening just after sunset.
- 'Cosmical setting'—CrB crosses the western horizon as the Sun crosses the eastern horizon. This is the first day (3 June) on which CrB (after a period when it had been visible) can be seen to set in the west at dawn or just before sunrise.
- 'Heliacal rising'—CrB and the Sun cross the eastern horizon together, but the observable so-called 'cosmical rising' is the first day (4 November) on which CrB becomes visible in the east at dawn. It crosses the eastern horizon shortly before sunrise and is thus briefly visible.
- 'Heliacal setting'—CrB and the Sun cross the western horizon together, but the observable 'acronychal setting' is the last day (4 December) when CrB (after a period when it had been visible) crosses the western horizon (and sets) shortly after sunset.

Among these four points where both CrB and the Sun are seen on the horizon, only two points were found that related to the orientation of the temple (30.26° north of east or south of west), i.e., the acronychal rising (CrB rises north of east at dusk in May) and the heliacal rising (CrB rises in the morning in November). However, the acronychal rising coincides with the *Vishākhā* month, which is associated with *Visakha Bucha* Day. In the above result of modern-day understanding, these rising and setting times were explored against the solar calendar, but in ancient times these events were related to the lunar calendar, which could also be used to in-

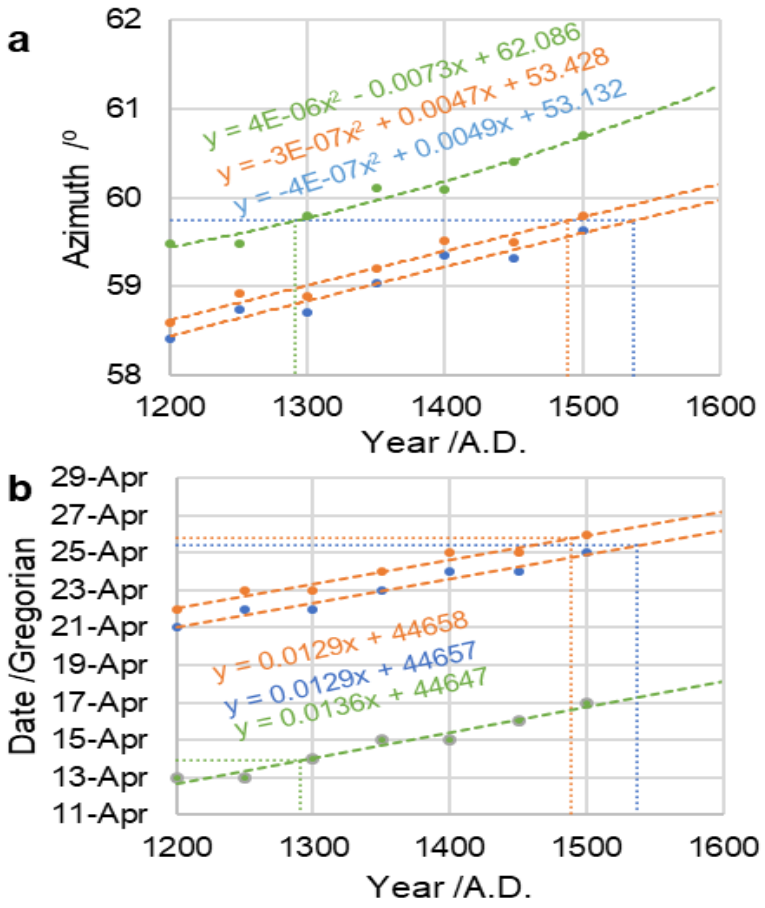

Figure 10a: The azimuths of Corona Borealis when rising as the Sun sets at the horizon ('true' acronychal rising). Figure 10b: The dates when acronychal rising occurs change with time. The dotted lines are linear least square regressions. The 'true' acronychal rising is indicated in orange (no atmosphere) and blue (with an atmosphere), while the expected 'visible' one is indicated in green (diagram: the authors).

dicate a leap day/morning.

It is to be noted that the 'visible' risings and settings occur shortly before sunrise or shortly after sunset when the sky is dark enough for the star to be visible in the morning or evening twilight. Since the 'apparent' phenomena are the only ones that can be seen, our investigated results based on the *Stellarium* calculation are referenced to the 'true' phenomena, which cannot be observed. The visible morning phenomena always follow the true morning phenomena, and the visible evening phenomena always precede the true evening phenomena, i.e., a week before in the case of CrB (in late April).

3.2.3 Time Period Relating Temple Orientation

The advantage of using a star as a primary indicator is that, unlike the Moon and Sun, its position does not change significantly over the course of a human lifetime. This could imply that the correlation of an identified stars' heliacal/acronychal rising or heliacal/cosmical setting with the seasons changes over time. This provides an additional method for determining the founding year of historical structures.

As mentioned in the previous Section, the acronychal rising of CrB is the only timing that fits the temple's orientation, and a phenomenon when the Full Moon in the *Vishākhā Nakṣhatra* is *Visakha Bucha* Day. Looking back to the past by using the *Stellarium* software, we obtain the time dependences of the CrB's azimuths and their corresponding dates when rising in the east when the Sun sets in the west, as presented in Figure 10. Three conditions for the acronychal rising of CrB were investigated as follows:

(1) no atmosphere;
(2) with atmosphere refraction; and
(3) accounting for the atmosphere extinction with the *arcus visionis*—the Sun below the horizon—of 11.35° and CrB's critical altitude of 2.2°, according to the values taken

from the astronomical PLSV software, which is calculated with the linear relation to star's magnitude derived from Schoch (1924). The latter was assuming optimal observing conditions for actual 'visible' phenomena, where the first two criteria were 'true' phenomena which were invisible just for comparison. We made no attempt to take into account the obstacles of weather, atmospheric transparency and ambient light, which are difficult or impossible to include in these calculations.

From Figure 10a, the azimuths of CrB observed at Phra That Doi Suthep Temple are now about 62°, changing by 1.5° over four hundred years, or about 2.5 centuries per degree. Results of the first two conditions—'true' acronychal rising observed just at the horizon, which cannot be observed in reality—(orange and blue lines) are slightly different (approximately ten minutes of arc), indicating that the refraction is unaffected by the naked-eye observation. However, for the third condition, where the temple is located on the mountain with an elevation of 1066 m, giving a dip angle of 24.8 minutes of arc below zero altitude, the azimuth decreases by less than half a degree. The astronomical twilight criteria used in the third condition are suitable for a 2nd magnitude star, but they are subject to a variety of factors, including atmospheric conditions; extinction; visual acuity of the observer; visibility of the horizon such as vegetation, and local topography; and the elevation and altitude of the horizon from the observer.

Figure 10b also shows that the shifts on such dates, eventually due to the precession of the equinox. The dates of acronychal rising varied significantly with observed altitude, with the third condition, known as the 'apparent' acronychal rising, occurring more than a week before the first two cases.

According to regression analysis for the first, second, and third conditions, the Phra That Doi Suthep Temple orientation of *az*. = 59.74 ± 0.07° coincides with the azimuth of CrB in 1456 ± 19, 1537 ± 19 and 1290 ± 20, when acronychal rising occurs on 26, 25 and 13 April (Gregorian) for 'true', 'true' with atmospheric refraction, and 'visible', respectively. It is interesting that it matches the period when King Mueangketklao reconstructed the stupa on 21 April 1538 and all the other buildings were built in 1543. Unfortunately, the second condition is not visible by naked eye at the horizon, so it could be accomplished by aligning the CrB with the horizon. However, because all the resulting years (1270 to 1556) fall within the same time frame as the historical record (1384 and 1538–1544 for the founding and reconstruction years, respectively), it is highly likely that the temple's orientation was associated with CrB.

3.2.4 *Visakha Bucha* Day Phenomenon

For the present official Thai Lunar Calendar, *Visakha Bucha* Day, which falls on the Full Moon day of the sixth (or seventh, if a leap-month year) lunar month, is on a different (solar) date each year, as shown in Figure 11a. The date goes one or two years back (solid line) and one year forward (dotted line) with a pattern of 3332 332 (detailed in Saelee et al., 2018), therefore the dates will be retained for a specific period, i.e., 6 May–4 June. Indeed, the date is associated with the position of the Sun on the ecliptic, which is also referred to as the zodiac; for example, on 15 May 2022 the Sun was in Taurus near the Pleiades, while the Moon was in the *Vishākhā Nakṣhatra* (see Figure 8; both were located in between the orange and green lines). Furthermore, the actual positions of the Full Moon, assuming they are opposite the Sun and computed as longitudinal coordinates in Figure 11b, fluctuate back and forth as well, but in a much-distorted pattern from the date one. The Full Moon's location on *Visakha Bucha* Day was almost perfectly aligned between CrB (the orange line) and Antares (the green line). The leap-month years are closest to Antares, whereas most of the ordinary years are closest to Libra and CrB. The leap-day years can also be noticed, for example, in the years 1997, 2000, and 2016, and in the years when the Moon was placed much earlier CrB was needed to add an extra day, i.e., 1987, 1990, 2014 and 2020. It is worth noting that while all the analyses were based on modern astronomical data (as a case study), the ancient people may have utilized different day/month-adding rules than we do now to synchronize their lunar calendar with the solar sidereal year. As a result, the position of their celestial body has altered somewhat from the currently defined position.

The fascinating fact about CrB's ascent is its high declination, i.e., it rises above the horizon longer than it sets below the horizon (more than 13 hours, see Figure 9). The acronychal rising date is the first day that CrB can be seen all night, and it will be visible all night for nearly two months (in theory, it can only be seen for one month) until the last day when it sets at sunrise (cosmical setting). For the year 2022 as see in Figure 9, CrB can be visible (by definition) overnight from 2 May to 3 June, but the actual observable period should be approximately from 21 April to 13 June. Figure 11a

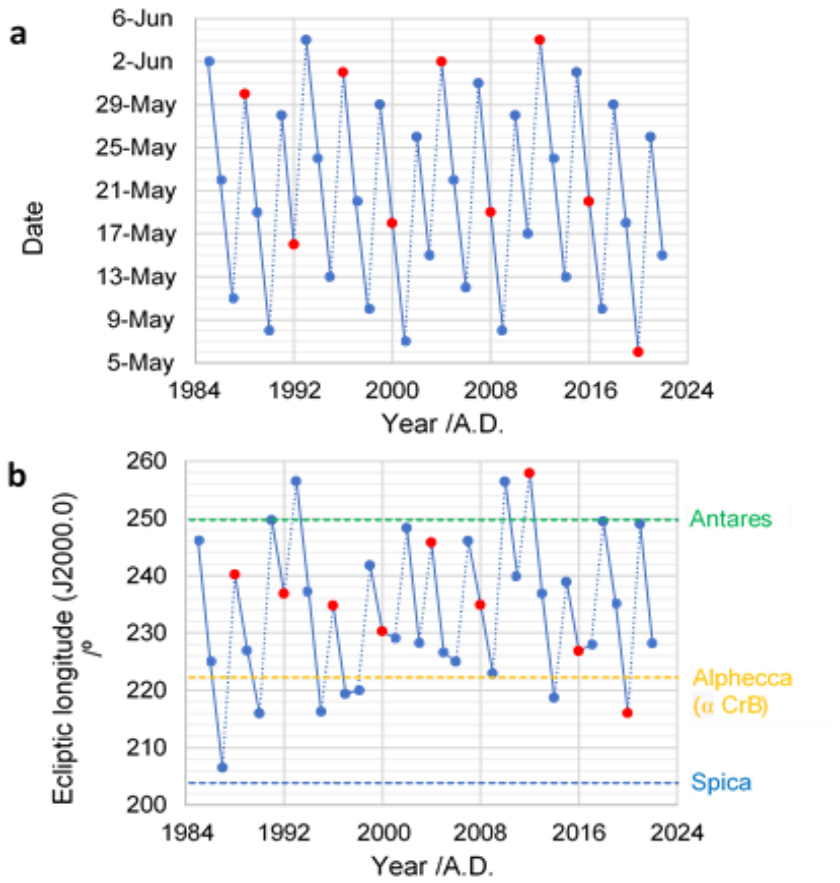

Figure 11: The date (a) and the Moon's ecliptic longitudinal coordinate at midnight (b) when it was *Visakha Bucha* Day on the official Thai Lunar Calendar over two periods of the 19-year-Metonic circle. Ecliptic longitudinal coordinates are used in the year 2000 for clarity. Leap years are indicated in red (diagram: the authors).

shows that the current *Vishākhā* months fall within the period of 20 April to 19 June, which is close to the period of all-night visibility of CrB. This indicates that each year the *Vishākhā* month, which is indicated by the Full Moon in the *Vishākhā Nakṣhatra,* must begin on the first Waxing Moon day, after spotting the acronychal rising of CrB. In other words, the acronychal rising of CrB might be related to the ancient Lanna alignment of Phra That Doi Suthep Temple with the *Visakha Bucha* Day. The importance and reasons for such a practice being adopted by the ancient Lannas can be explained in two ways:

(1) by synchronizing the *Visakha Bucha* Day with a season or even the sidereal year to determine an intercalation year; and
(2) by reckoning the Buddhist year elapsed after the Buddha's Parinirvāṇa (death) day. Although today *Visakha Bucha* Day is known as a Full Moon day in the sixth lunar month, CrB is still in the vicinity of the Full Moon, and more importantly, the tradition of walking up the mountain on the eve of *Visakha Bucha* Day for auspiciousness still lives on.

4 CONCLUDING REMARKS

This study investigated whether Wat Phra That Doi Suthep, the most revered Buddhist temple in the Lanna Kingdom, was oriented in accordance with ancient astronomical practices to manifest important events. We analyzed connecting traces of historical evidence and hypothesized that the constellation of Corona Borealis (CrB) might have been used to orient the temple on the Full Moon *Visakha Bucha* Day in commemoration of the Buddha and to signal the start of a New Year of the Buddhist *Nirvāṇa* Era Calendar.

Understanding the precession of the equinox leads to an estimation of the ancient sky. Using modern, precise tools (a theodolite and the *Stellarium* software), the visualized sky was simulated under three atmospheric conditions. We found that the azimuth of 59.74 ± 0.07° of the Temple coincided with the azimuth of α CrB

in 1456 ± 19, 1537 ± 19, and 1290 ± 20. However, under the astronomical twilight condition, AD 1537 ± 19 was the most likely date to observe the true acronychal rising of CrB for the temple's alignment. This period overlaps with the planning period to restore King Mueangketklao's Chedi to a larger stupa on the *Visakha Bucha* Day, or 21 April 1538 (Gregorian). Despite the fact that the actual ancient atmosphere is unknown and that the true acronychal rising of CrB might be invisible to the naked eye, we believe that the orientation of the Temple was most likely related to CrB because all of the resulting years (ranging from AD 1270 to 1556) fall within the same time period as the historical record (AD 1384 and 1538–1544 for the founding and reconstruction years, respectively).

More research into archeoastronomy will help us better comprehend the scope of the practices described here. Investigations that consider astronomical observations made from the temple during construction will provide a better understanding of the ancients' experience with traditions. For future work, we plan to pursue other revered locations, for example, Wat Phra That Doi Tung in Chiang Rai, northern Thailand. This temple, which was also built by King Kuena, and was restored by King Muengketklao, has the same orientation as Wat Phra That Doi Suthep when viewed from a satellite. We hope that our findings contribute to a better understanding of the wisdom and heritage of ancient Lanna that revolves around ancient astronomy, and provide another perspective on ancient cultures that are deeply entwined with celestial phenomena. Ancient wisdom that contributes to the creation, inspiration, motivation, and prosperity of the society it originated is worth treasuring and investigating. The ultimate goal of this research is that when we look at selected ancient sites we will appreciate what brought them into existence, and we will seek to preserve them for future generations.

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