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THE ASTRONOMICAL ORIENTATION OF THE THAI PHIMAI TEMPLE

Cherdsak Saelee
Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai50200, Thailand.
E-mail: cherdsak.s@cmu.ac.th

Orapin Riyaprao and Korakamon Sriboonrueang
National Astronomical Research Institute of Thailand, Chiang Mai, Thailand.
E-mails: orapin@narit.or.th ; korakamon@narit.or.th

Siramas Komonjinda
Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand.
E-mail: siramas.k@cmu.ac.th

and

Prissana Thamboon†
Office of Research Administration & Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, 239 Huay Kaew Rd, Suthep, *Chiang Mai 50200, Thailand [author for correspondence].*
E-mail: prissana.t@cmu.ac.th

Abstract: In this paper we examine the orientation of Prasat Hin Phimai (an Angkorian-style Buddhist temple in Northeast Thailand) for its astronomical embodiment that could enrich the understanding of ancient culture and potentially date the temple. The obliquely-oriented Phimai Temple may have been aligned with an auspicious star observed relative to the Sun on the horizon, according to the ancient Indian *Vastu Shastra* principles of architecture. By comparing the azimuth of the temple, which was archaeoastronomically surveyed on-site, to that of stars estimated using precessional-corrected *Stellarium*, we discovered that only the Pleiades was aligned with the temple's Eastern Gate at approximately 69.5° azimuth during the Khmer era. Further validation through traces of ethnoastronomy revealed that the Pleiades Full Moon Day (a Full Moon with the Pleiades) opposite the Sun in Scorpius may have been favored for aligning the temple, giving rise to an approximate period of orientation, and consequently the building of the original temple between 1007 and 1147 CE. These findings suggest a close connection with Mon Culture, a possible architect, and a potential patron. A New Year celebration and the entrance to the temple may have related to *Agni*, the presiding deity of the Pleiades.

Keywords: Phimai Temple; Pleiades; temple orientation, *Vastu Shastra* principles; archeoastronomy; ethnoastronomy.

1 INTRODUCTION

Astronomical wisdom played a crucial role in ancient culture and was embedded in a variety of cultural elements, such as calendar systems, customs, traditions and sacred structures. Many civilizations of antiquity, including ancient Greeks (Penrose, 1893; 1901), Mayans (Aveni, 1979), Chinese (Chu, 1947), Indians (Rajani and Kumar, 2019; Rao, 1992), Javanese (Magli, 2020), and Khmers (Magli, 2017), oriented their temples or palaces, with certain purposes, to celestial bodies such as the Sun, Moon, bright planets and stars. Thailand was once home to several ancient communities, states, and kingdoms, whose heritage included the fascinating sights of historic cities and religious temples dispersed throughout the country, many of which are still unstudied. Each ancient community even has its own concept and implementation of astronomy. For instance, different ancient ethnic groups formed diverse perceptions of the Pleiades star cluster. Thus, it was imagined as 'a flag' for the ancient Khmer people, 'a hand fan' for the Lanna people, and 'a herd of chicks' for the Mon people (Tumtong, 2017: 101, 135; Wisandarunkorn, 1997: 257). Uncovering the astronomical connection to sacred sites in Thailand through archaeoastronomy and ethnoastronomy can therefore deepen our understanding of the past or perhaps shed light on previously unknown aspects.

In this paper, we investigate the astronomical orientation of Prasat Hin Phimai, an Angkorian-style Buddhist temple, that may have been influenced by the ancient Indian *Vastu Shastra* principles of architecture. In what follows, we briefly introduce the uniqueness of Phimai Temple and overview the *Vastu Shastra* principles in connection with temple construction, prior to forming our hypothesis that the Phimai Temple may have been aligned with a favorable star.

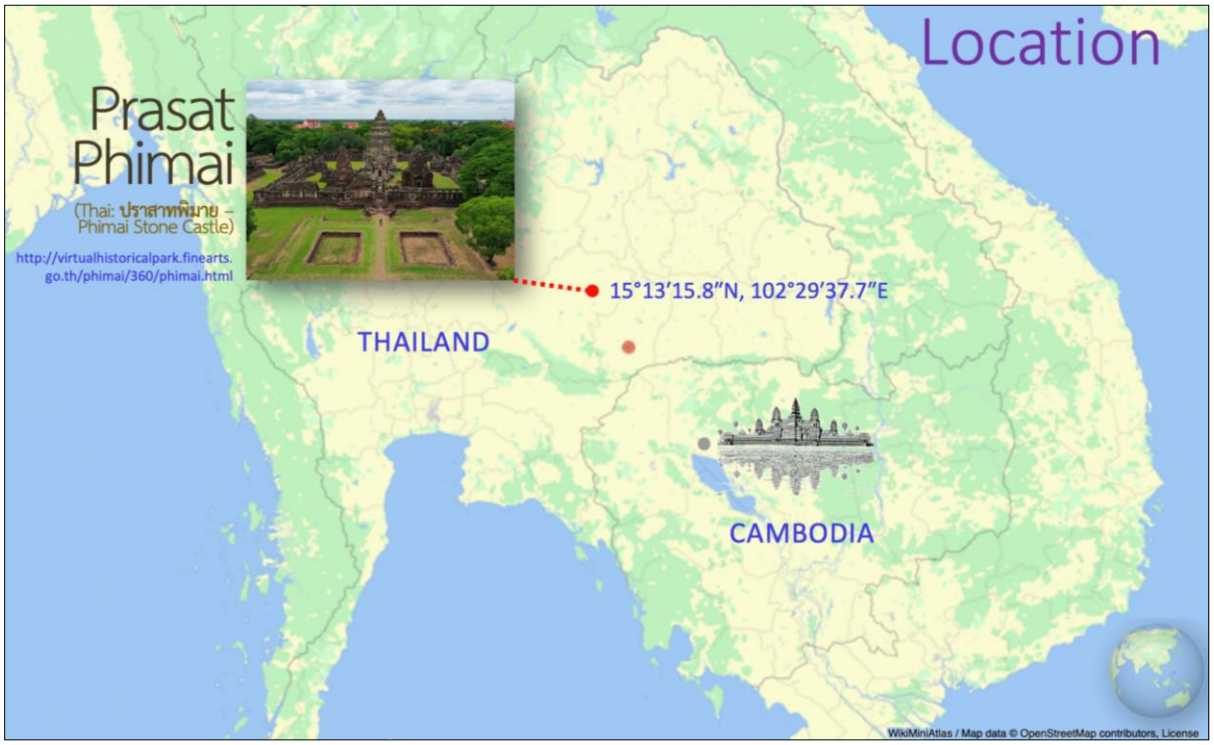

Figure 1: Geographic location of Prasat Phimai in Nakorn Ratchasima Province, Thailand (Map data copyrighted OpenStreetMap contributors; https://www.openstreetmap.org/copyright, and available from https://www.openstreetmap.org).

1.1 Prasat Phimai: A Temple of Mixed Religious Faiths

Prasat Phimai (15° 13′ 15.8″ N, 102° 29′ 37.7″ E; GMT+7) stands 28 meters tall, and is in the center of Phimai historical city, located in Phimai district, Nakorn Ratchasima Province, Northeast Thailand (see Figure 1). The name engraved on the front lintel of the main *Prasat* (or temple) written in Khmer as *Vimayapura*, meaning 'Vimaya city', is probably the original name that has been mispronounced to Phimai today. With rivers and creeks running through the fertile plain, there is archaeological evidence that ancient Phimai city was occupied during the Iron Age, as witnessed by kiln-fired pottery called 'Phimai Black', iron tools and weaponry, and water moats around the perimeter of a square-shaped wall (Meacham and Solheim, 1980; Tummakorn, 2015: 29).

Then, around the seventh to eighth centuries, the ancient Mon people, the creators of Dva-ravati Culture from Central Thailand, came and settled the region, as evidenced by sporadic traces of Dvaravati-style stupas (Tummakorn, 2015: 36). The Mon were transmitters of Indian culture, particularly Theravada Buddhism, through early commercial and cultural contact with India (Coedes, 1965). East of Phimai City, the Khmer Empire rose to prominence, and from the eighth century on, Khmer Culture, influenced by Hindu and Mahayana Buddhist beliefs, eventually superseded Dvaravati Culture in this area. It is believed that Phimai Temple was built during this time.

According to artifact analyses, including inscriptions, carvings, artwork and architectural style, Phimai Temple may have been built and renovated during the eighth to twelfth centuries by multiple Khmer rulers, whose religious faiths in Hinduism and Buddhism were expressed in the temple (Tummakorn, 2015: 36–38). The roof is shaped like a lotus bud, which resembles Angkor Wat, a Vishnu Hinduism temple. The wall carvings also depict various *Ramayana* epics and several of Vishnu's avatars, including *Krishna*. On the other hand, the image of Buddha sheltered by *Naka* (serpent) Hood is housed in the innermost sanctum known as the Garbhagriha, and there are several 4-face, 8-arm Bodhisattva statues spread throughout the temple. The image inside the Garbhagriha has traditionally been regarded as the primary deity to whom the temple is dedicated; for example, in Hinduism, the image would be *Vishnu* or *Shiva* (usually a linga), whereas in Buddhism, the image would be Buddha or Bodhisattva. As a result, Phimai Temple is considered a Buddhist temple, most likely of the Vajrayana, a Mahayana Buddhist school widely accepted in the Khmer Empire. After King Jayavarman VII (r. 1181–1218) endorsed the last and major renovation of Phimai temple, which included the

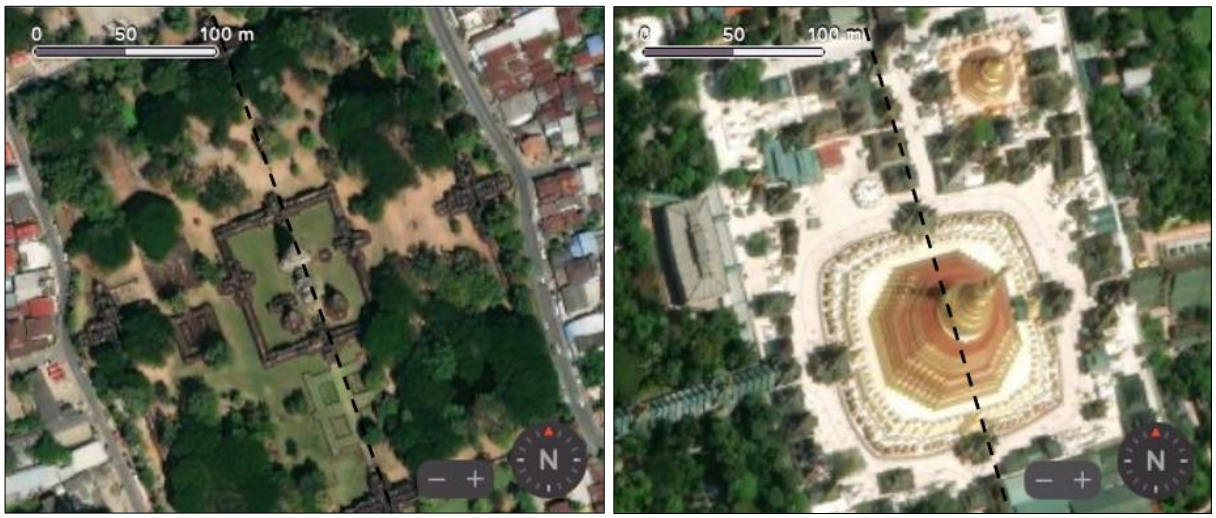

Figure 2: Satellite photographs of Phimai Temple in Thailand (left) and Shwedagon Pagoda in Myanmar (right). The black dashed lines are drawn through the main halls along the entrances to the temples. (Map data copyrighted OpenStreetMap contributors (https://www.openstreetmap.org/copyright) and available from https://www.openstreetmap.org)

construction of a rest area for pilgrims and hermits as well as additional pagodas, one of which houses a sculpture of the King-alike, Phimai Temple became less significant to the Khmer regime.

However, the orientation of Phimai Temple deviates from the primary cardinal directions (see Figure 2, left), which sets it apart from other Khmer temples. Instead, it bears a striking resemblance to Shwedagon Pagoda, a Theravada Buddhist temple located in Myanmar (see Figure 2, right). Both places, despite being far apart, share traces of the Mon Culture, suggesting that the same orientation principles may have been applied to both temples. Furtheremore, the temple's entrance, located at the Southern Gate, is a debatable topic with different explanations among scholars. Some suggest that the entry is aligned with the road or the direction towards Angkor, the Khmer Empire's capital city (Chanbai, 2002). However, Charernsupkul (1987, cited in Chanbai, 2002: 30) remarks that none of the other Thai Khmer temples face Angkor. Other theories revolve around two opposing beliefs: one holds that the South is the direction of life according to Mahayana Buddhism (Jiachantrapong, 1997), while the other believes that *Yama*, the God of Death, rules the South and that the temple was built as a memorial to ancestors (Jacques, 1997: 150). The oblique orientation and the entrance of Phimai Temple may be explained by the Indian architectural rites and rules called *Vastu Shastra*.

1.2 *Vastu Shastra* Principles: Orientation Under an Auspicious Star

Owing to the transmigration of Indian culture during the Dvaravati and Khmer eras we have discovered that many ancient sites around Thailand embraced the traditional Indian *Vastu Shastra* architectural principles, which govern the establishment process of a temple, a town, a city, or even a house (Komonjinda et al., 2019; Riyaprao et al., 2023; Saelee et al., 2021). *Vastu Shastra* is rooted in Vedic tradition, and initially was transmitted verbally among highly intellectual sages who had to be well versed in science and religious rites. After the sixth century, it started to appear in Sanskrit texts, including the *Brihat Samhita*, the *Samarangana Sutradhara* and the *Mayamata*. The process included guidelines for choosing a site, selecting an auspicious orientation, performing rituals, and so forth, to the final construction (Kramrisch, 1976). There are two inscriptions at Phimai Temple hint at the involvement of *Vastu Shastra* principles: the oldest Phimai inscription (K.100), which is dated to the early eleventh century, mentions a sage and the completed work (Princess Maha Chakri Sirindhorn Anthropology Centre, 2023a), and the Wat Chong Ko inscription (K. 1249), which was written in 1007–1008 CE at a nearby temple, describes the Khmer King Jayavirahvarman (r. 1002–1006) ordering a cadastral survey of the land and dedicating it to the Vimaya's *deva* (Princess Maha Chakri Sirindhorn Anthropology Centre, 2023b).

The guidelines for the orientation of a temple center around the creation of a ritual diagram called *Vastu–Purusha–Mandala* (*site–cosmic–plan*) for a harmonious connection between the Universe and a dwelling on the Earth. The ritual plan is founded on divination beliefs in association with celestial bodies and directions. For instance, Figure 3 (left) depicts eight gods who

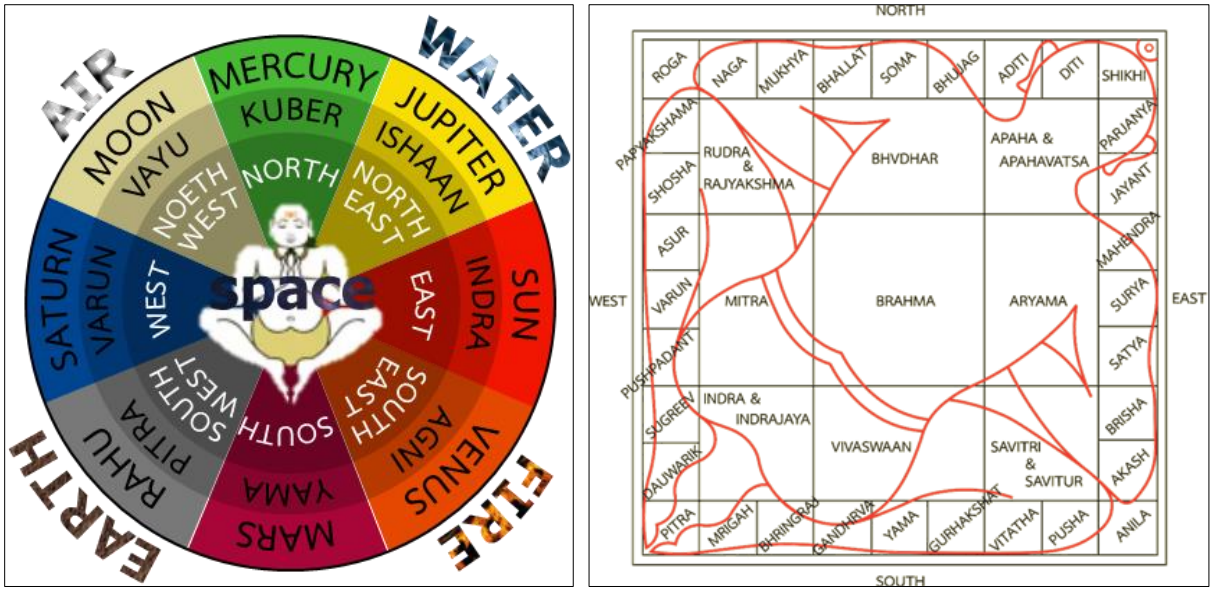

Figure 3 (left): A diagram showing gods ruled in the eight directions according to Vastu Shastra principles (after Kramrisch 1976: 33; Sastri and Bhat, 1946: 666). Right: An example of a 9 × 9 *Vastu–Purusha–Mandala* according to the Brihat Samhita, as extracted from Chapter LIII Slokas 42–56 of Brihat Samhita's treatise in Sastri and Bhat (1946: 434–439).

rule over the Sun, Moon, and one of the planets in each of the eight cardinal directions. Some of the gods can be worshipped through sacrificial elements; for example, fire or fire-like objects would be sacrificed to the God of Fire, *Agni*. Depending on the *Vastu Shastra* texts used, the square mandala like the one in Figure 3 (right), is divided into grids of 8 × 8 or 9 × 9 ideal for temples (Kramrisch 1976: 6). Divinities are assigned to the outermost border of the *Vastu* square; the 8 × 8 square can accommodate 28 divinities, whereas the 9 × 9 square allows 32 ones. The number 32, being the sum of 4 and 28, could refer to the regents of the four cardinal points associated with the Sun and the regents of the 28 lunar mansions (or *Nakshatras*) affiliated with the Moon; thus, the *Vastu* plan in this manner is considered the adjustment of solar and lunar cycles (Kramrisch 1976: 31). Currently, it is more common to divide the ecliptic into 27 *Nakshatras* rather than 28, each encompassing about 13° 20′ and marked by a prominent star or asterism. Each Nakshatra is assigned its own presiding regent, whose name may be given differently in the various treatises. For instance, the Sun God for the *Hasta Nakshatra* is *Savita* according to the Yjurveda treatise (Saha and Lahiri, 1992: 220), but is *Surya* in the *Brihat Samhita* treatise (Kramrisch, 1976: 34). However, the border divinities in Figure 3 (right) are not entirely *Nakshatra* regents, as some ill-fated divinities are usually omitted from the *mandala*. The square *Vastu–Purusha–Mandala* must be drawn on the site prior to construction so that the deities can be ritually invoked to their allocated positions in the *mandal*a and stay to protect the site.

To form the *Vastu* square, typically, the East–West line, which symbolizes the merging of heaven and Earth at sunrise and sunset, is established first, followed by the line perpendicular to it (the North–South line). Traditionally, ancient Indians employed two methods for establishing the East–West line: a gnomon and a fixed star (Yano, 1986). Using a gnomon to cast the Sun's shadow, known as the Indian Circle, is highly accurate because it allows an error from due East of <0.5 degrees (Burgess et al., 1935: 108). Temples that are not aligned with the cardinal East–West axis, like Phimai Temple, are therefore likely to be oriented using the fixed star method. The utilized star would have been the one observed at sunrise or sunset, meaning it is either with or opposite the Sun on the horizon. The fixed star method conforms to the *Vastu* orientation rule, which states that the orientation is under a favorable star (Kramrisch 1976: 248); the axis of orientation thus becomes the favorable star's horizontal (or azimuthal) axis.

Because Phimai Temple was built for Indian-based religious faiths and with an oblique orientation, we hypothesize that the temple may have been aligned with a favorable, auspicious, star in accordance with *Vastu Shastra* principles. As this was traditionally reserved knowledge, retained for example within Brahmin families, a public record of how the temple was oriented might not be attainable. Nonetheless, by taking advantage of the Earth's precession, which effectively shifts stars from their positions

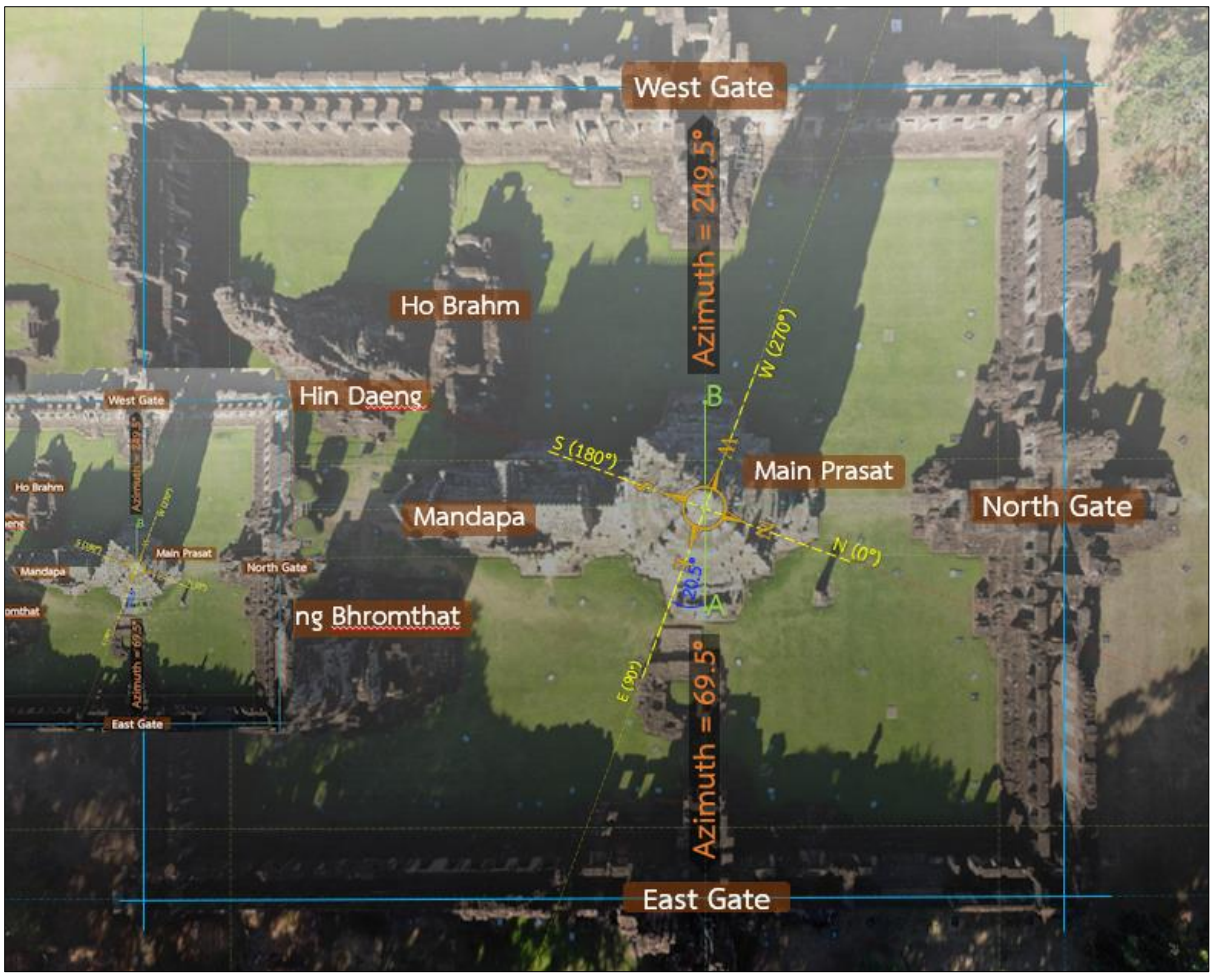

Figure 4: Archaeoastronomical site survey at Phimai Temple (on 20 November 2018). This bird-eye-view view is modified from Phimai Historical Park (n.d.).

at a rate of about one longitudinal degree in 72 years, the orientation involving a star can thus be time-traced and the star can be identified. By employing archaeoastronomical surveying, using a theodolite and Stellarium software, and conducting ethnoastronomical analysis of available evidence, we were able to identify and validate the star of orientation, which then allowed us to extract a specific astronomical event at the time of orientation and estimate the date when the temple originally was built. The findings can explain the resemblance of Phimai Temple to Shwedagon Pagoda and the position of the temple's entrance.

2 METHODOLOGY

For the stellar orientation according to *Vastu Shastra* principles, the axis of orientation of the temple must be established with reference to the Sun on the horizon. We utilized the azimuth angle, a horizontal angle measured clockwise from North, to indicate the orientation of Phimai Temple and that of the star. Horizon-based astronomy had been widely practiced in tropical latitudes because the azimuth angle is relatively constant up to elevated altitudes (Aveni, 1981). Based on Stellarium, the azimuth of the temple was measured on-site, whereas the azimuths of various stars were obtained through calculation; after that, they were compared to find a match during the Khmer era. The astronomical coordinates of celestial bodies were obtained from the Stellarium calculations. Stellarium is free GPL software that renders realistic skies in real time with OpenGL (Zotti et al., 2021). We employed the software package version 0.20.3 with DT correction using the default 'Espenak and Meeus (2006)' model, accounting for atmospheric refraction and extinction, and proper motion. A portable GPS device provided the observed location as the required input parameter for the Stellarium calculation.

2.1 Measuring Phimai's Azimuth Angle

Using our archaeoastronomical site-survey technique as detailed in Riyaprao et al (2023), the line A–B in Figure 4, which is parallel to the East and West Gates of the main Prasat, serves as the baseline of 16.1 m for horizontal and vertical angle measurement via a theodolite.

The horizontal and vertical angles of two reference stars, i.e., Polaris and the Pleiades, were measured with respect to the baseline at different times and then were calibrated with their azimuth angles calculated using Stellarium software. The offset value from the calibration was therefore the azimuth angle of the baseline, in other words, the azimuth of Phimai Temple.

2.2 Determining a Star's Azimuth Angle

As a result of precession stars gradually shift their ecliptic longitudes over time, and alter their azimuth angles. We employed precession-corrected Stellarium on various stars to obtain their azimuths over time, tracing them back to the Khmer era. The star (or stars) of orientation is one with the same azimuth as Phimai Temple, which could be aligned with either the East or the West Gate of the temple. The behavior of such a star on the horizon with respect to the Sun (i.e., how it rises or sets with or opposite the Sun) is further determined by an analysis of its cultural significance.

2.3 Analysis of Cultural Significance, Orientation Timeframe, and Temple Entry

The star of orientation should be favorable in accordance with the *Vastu Shastra* principles, suggesting its importance in the lifeways of the Phimai community. Hence, to validate the result from the matching azimuth, we searched for traces of cultural elements relevant to the star, such as calendars, customs, or traditions, which also helped identify the star's behavior on the horizon and thus allowed us to date the temple using the Stellarium calculation. The debatable position of the temple entry was also explained in terms of *Vastu Shastra* principles.

3 RESULTS AND DISCUSSION

Prasat Hin Phimai, with its oblique orientation, may have followed *Vastu Shastra* principles to align with a favorable star observed on the horizon with reference to the Sun. The results reveal the matching azimuth angles of the temple, measured from archaeoastronomical site-surveying, and the star, obtained from the Stellarium tracing. The link between the star and the temple was then explored, which helped to further specify the astronomical event at the time of the orientation, allowing for a dating analysis of when the temple was first built.

The findings include a discussion of the orientation relating to Mon Culture and why the temple's entrance faces towards the Southeast.

3.1 Matching Azimuth Angles of Phimai Temple with the Pleiades

From our archaeoastronomical site survey, the azimuth angles of Phimai Temple at the East and West Gates were 69.5° ± 0.1° and 249.5° ± 0.1°, respectively. In other words, the temple is oriented 20.5° ± 0.1° from the East Northward or from the West Southward. The orientation is within the solar range between the solstices, resulting in four scenic events of sunlight shining through the doorway at each gate (two sunrises on 17–18 May and 22–23 July, and two sunsets on 22–23 January and 20–21 November). On the other hand, the azimuth angles of various stars changing over time are calculated by precessional-corrected Stellarium at Phimai Temple and plotted in Figure 5, covering the Khmer period. The x-axis displays the azimuth on the Eastern horizon as a star rises and the corresponding azimuth as it sets on the Western horizon. By overlaying the azimuth angles of the temple at the East and West Gates in Figure 5, we found that during the Khmer period, the azimuth of the temple's East Gate at 69.5° overlapped with that of Pleiades, whereas there is no overlap of azimuth angles at the West Gate. This result indicates that the Pleiades on the Eastern horizon may have been chosen to align the temple.

Ancient people observed the stars with respect to the Sun at or close to the horizon. As a result of a shorter sidereal day, stars rise and set four minutes earlier on subsequent nights, leading to four types of rising and setting of a star with respect to the Sun each year. The names of these four events are inconsistent; however, we adopt the following convention, as illustrated in Figure 6 where the cluster of stars represents the Pleiades:

- A star is opposite the Sun, i.e., a star sets as the Sun rises (the cosmical setting (CS) type), or a star rises as the Sun sets (the acronychal rising (AR) type)
- A star is with the Sun, i.e., a star rises as the Sun rises (the heliacal rising (HR) type), or a star sets as the Sun sets (the heliacal setting (HS) type).

In Figure 7, the rising (green diagonal line) and setting (red diagonal line) times of the Pleiades at Phimai Temple for the year 2023, calculated by Stellarium, are plotted, whereas the daily sunrise and sunset times are provided as the horizontal lines. The four events (HS, HR, AR, and CS) of the Pleiades are indicated at the intersections of the Pleiades lines with sunrise and sunset lines. Since the azimuth of Pleiades matches that of Phimai Temple at the East Gate, we can rule out the HS and the CS of the Pleiades. Investigating how the Pleiades

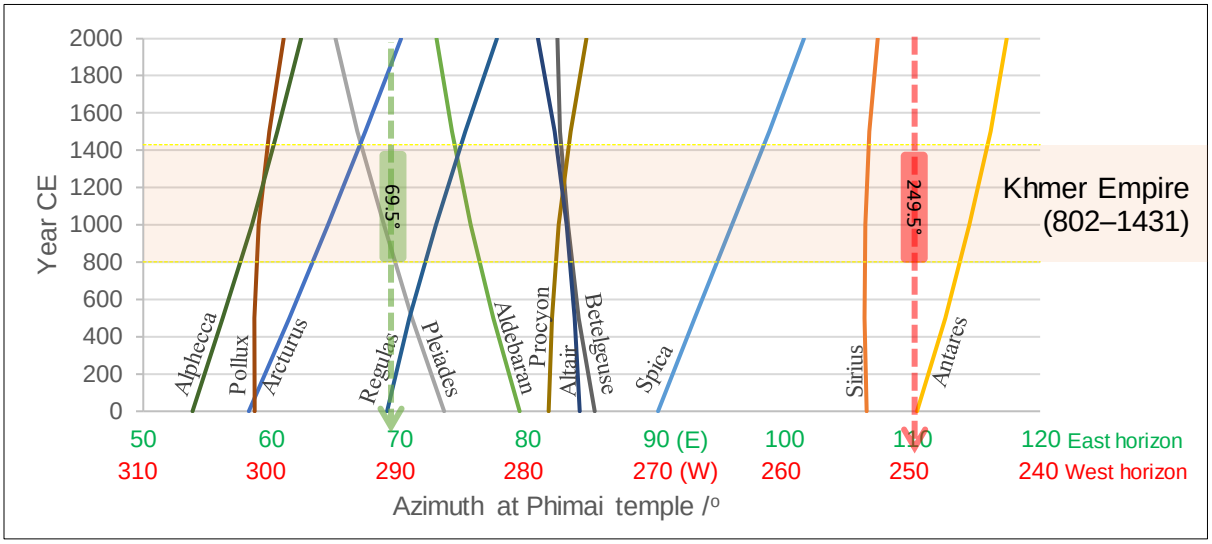

Figure 5: The azimuths of various stars changing over time as calculated at Phimai Temple using precessional-corrected Stellarium. The period of the Khmer Empire is indicated by a highlighted band. The green dashed line (at 69.5°) and the red dashed line (at 249.5°) denote the azimuth of the Temple at the East Gate and the West Gate, respectively.

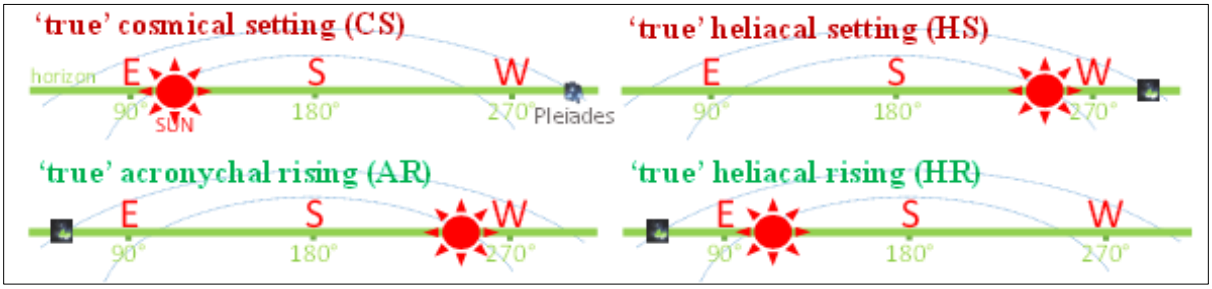

Figure 6: Four types of rising and setting of a star (represented by a black cluster) with respect to the Sun at the horizon.

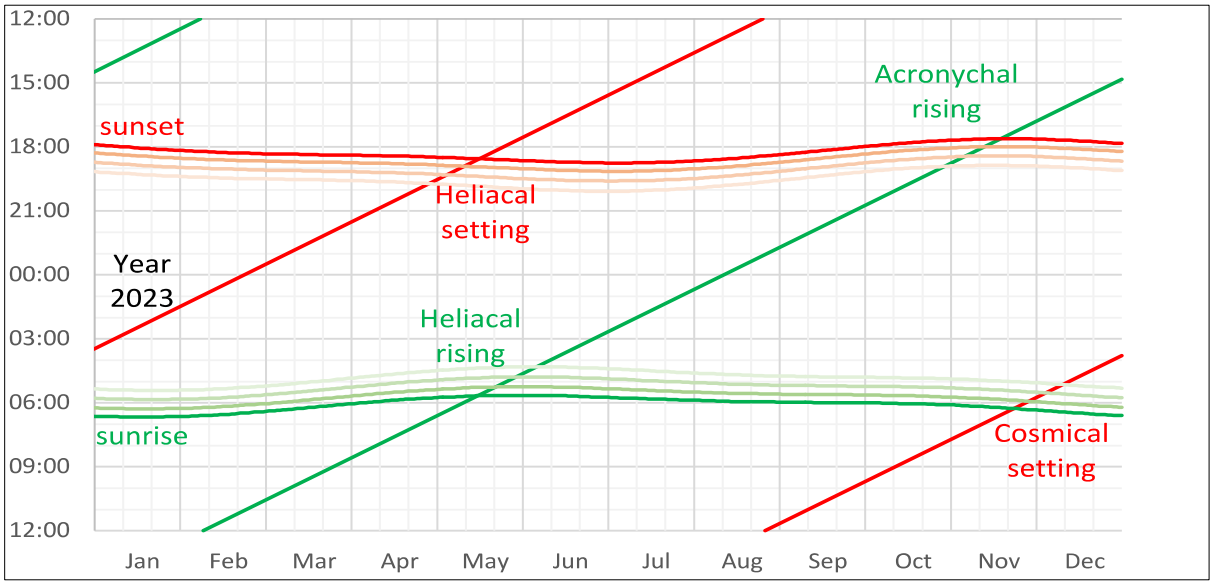

Figure 7: Rising times (green diagonal lines) and Setting times (red diagonal lines) of Pleiades at Phimai temple during 2023. The bold horizontal lines are daily sunrise and sunset times on the horizon obtained from Earth System Research Laboratories (2023). The faint horizontal lines are the Civil, Nautical, and Astronomical Twilights, which are obtained from Time and Date (2023).

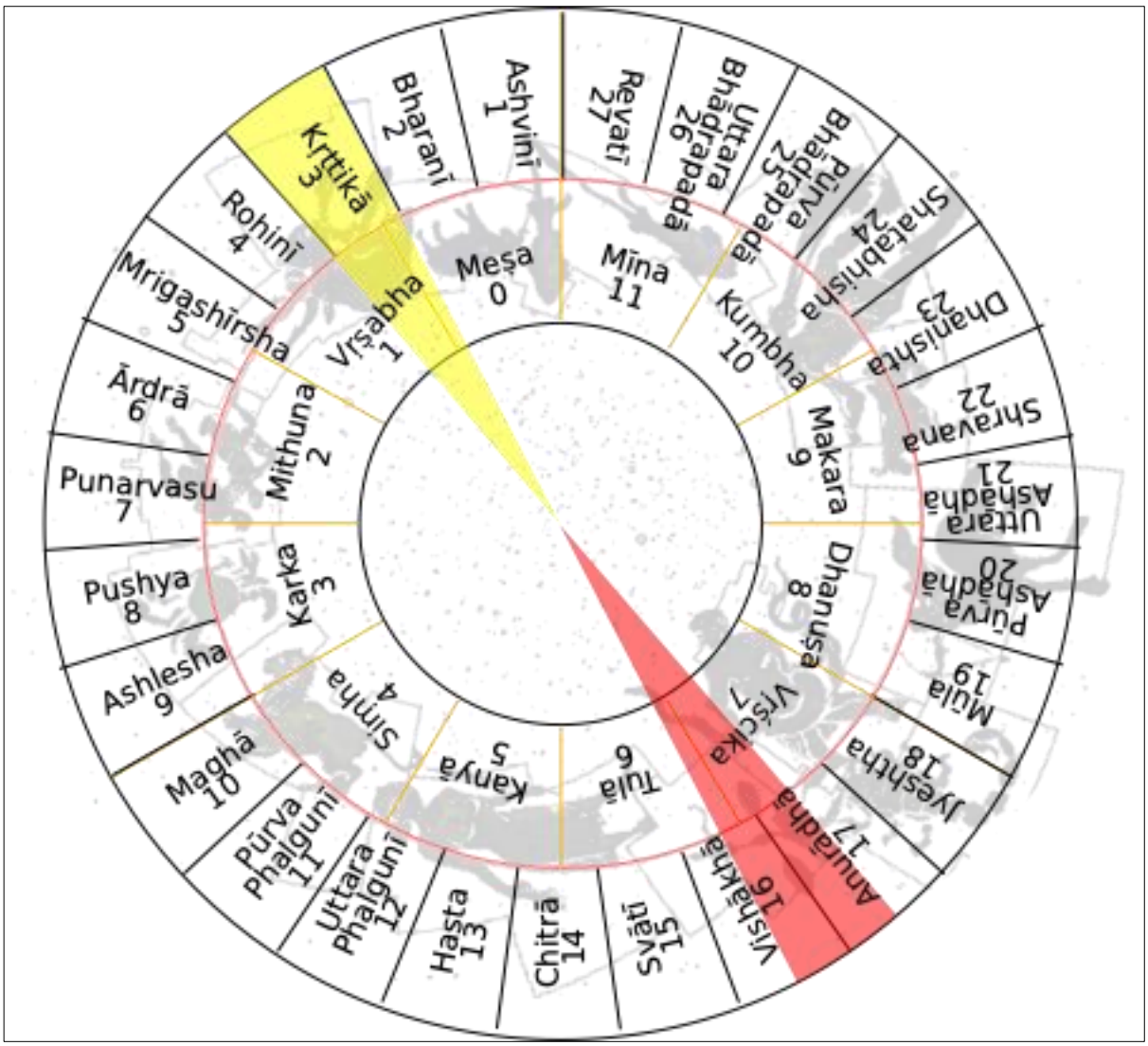

Figure 8: A sky map depicting the division along the ecliptic into 12 (sideral) zodiac constellations (the inner circle) for the Sun's path and 27 *Nakshatras* (the outer circle) for the Moon's path. The Full Moon (the yellow band), which is opposite the Sun (the red band), emerges with the Pleiades or *Krittika* defines the *Krittika* lunar month.

may have been favored for the orientation of Phimai Temple should help specify which rising type of Pleiades (HR Pleiades around May or AR Pleiades around November) may have been used for the alignment.

3.2 The Importance of the Pleiades in Connection With Phimai Temple

According to Hindu astrology and Indian astronomy, the Pleiades (*Krittika*, in Sanskrit) is ruled by *Agni*, the God of Fire, and is the leading star that represents *Krittika Nakshatra*. The sky map in Figure 8 depicts the ideal divisions of 12 sideral *Rasi* (zodiac constellations) and 27 *Nakshatras* along the ecliptic. Out of the 27 *Nakshatras* there are 12 lunar months designated by a *Nakshatra* that houses a Full Moon, which effectively indicates the Sun's location on the opposite of the ecliptic. The *Krittika* lunar month thus identified by the Full Moon emerging with the Pleaides, corresponds to the Sun entering *Vrishchika*, or the constellation Scorpius. Consequently, the time for the *Krittika* lunar month corresponds approximately to the month of November in the solar year. The *Krittika* Full Moon Day around 2300 BC during the Vedic and Mahabharata periods was used to mark the autumnal equinox, whereas the Full Moon in the *Visakha Nakshatra*, as the Sun entered *Vrishabha* (Taurus), was the vernal equinox (Saha and Lahiri, 1992: 200, 254–255). Several important Indian calendars, such as the Vikram Samvat Calendar and the Saka Calendar, once used the autumnal equinox, or the *Krittika* Full Moon Day, as the transition to a New Year. It should be noted in this context that the autumnal and vernal equinoxes pertain to the Northern Hemisphere; at present, they are also known as the September and March equi-

Table 1: Calibration of three events from the Prasat Hin Phimai Inscription 3 (K. 397) to Gregorian dates (with Julian dates in parenthesis) based on NYD cases and the lunar month counting system.

Date inscribed in K. 397*	NYE on the *Krittika* Full Moon Day		NYD on the *Thaloeng Sok Songkran*	
	Amanta	*Purnimanta*	*Amanta*	*Purnimanta*
1030 MS, 8th waning of month 2, *Sunday*	Wednesday 15(8) January 1108	*Sunday* 15(8) December 1107	Sunday, 3 January 1109 (27 December 1108)	Saturday 5 December (28 November) 1108
1031 MS, 6th waning of month 1, *Wednesday*	Thu, 3 Dec (26 November) 1108	*Wed*, 4 Nov (28 October) 1108	Monday 22(15) November 1109	Sunday 24(17) October 1109
1031 MS, 5th waxing of month 2, *Wednesday*	*Wednesday* 16(9) December 1108		Monday 6 December (29 Nov) 1109	

Note *:
Month 1 is *Mārgaśirṣa*, the first month of the current Thai Culasakaraj Calendar.
Month 2 is *Pushya*, the second month of the current Thai Culasakaraj Calendar.

noxes, respectively.

Traditionally, there are two systems to count one synodic lunar month: either the Full Moon ending (*purnimanta*) or the New Moon ending (*amanta*). For the Full Moon ending system, this means the *Krittika* Full Moon Day is the last day of *Krittika* lunar month, and therefore it would be equivalent to the New Year's Eve (NYE) of a lunar calendar. In this case, the next day, which is the first day of the waning Moon, would be New Year's Day (NYD). Later in the sixth century, based on the *Pancasiddhanta* treatise (a compendium of astronomy written by a prominent Indian astronomer Varahamihira), the vernal equinox was redefined as the Sun entering *Mesha Rasi* (Aries), and was designated as NYD. Despite shifting of the vernal equinox due to precession, this definition of NYD continues to be in use, including in the luni-solar Thai Culasakaraj Calendar, where this day is now known as the *Thaloeng Sok Songkran* in Thai (Gislén and Eade, 2019). Further details about Indian calendars vary by factors such as eras, regions, and religious beliefs, as well as where they have been adopted in other countries, are discussed by Saha and Lahiri (1992: 249–258), whereas the adoption of luni-solar calendars in Thai kingdoms is discussed by Riyaprao (2003).

To determine which calendar system was used in Phimai Temple, we examined three dates describing donation events at the temple as recorded on the Phimai Inscription K. 397 (Princess Maha Chakri Sirindhorn Anthropology Centre, 2023c). The calibration of these dates to Gregorian dates is performed using a similar method to Gislén and Eade (2019), based on four possible calendar schemes: the *amanta* lunar month or *purnimanta* lunar month for NYE on *Krittika* Full Moon Day, or NYD on Thaloeng Sok Songkran, as shown in Table 1. These dates are extremely useful because they provide information about the year, the lunar phase, the lunar month (referred to by number), and, most importantly, the day of the week. We find that the 'days' of these dates exactly correspond to the calibrated 'days' in the case of the Full Moon ending system for NYE on *Krittika* Full Moon Day (as highlighted in *italics* in Table 1), implying that this is the calendar system that was used at Phimai Temple. Based on this calendar system, we further discover that the year written on the Phimai Inscription K. 953 (Princess Maha Chakri Sirindhorn Anthropology Centre, 2023d) matches the year naming system of the Mon Calendar, which takes the name from the *Nakshatra* that houses Jupiter on the *Krittika* Full Moon Day. It is interesting that the Mon Calendar of the previous inhabitants continued to function in the Phimai area even after the Khmer took over the region. To the Mon Culture, *Krittika* is perceived as the 'herd of chicks' star, and it is of importance for alerting Mon seafarers of the arrival of the southwest monsoon in *Krittika* lunar month. It is possible that Phimai Temple was designed and built by a *Vastu Shastra* architect who was influenced by Mon Culture and therefore chose a favorable asterism, *Krittika* (Pleiades), for alignment, possibly at Full Moon when the Sun would be opposite *Krittika*. This may explain the similar orientation of the Phimai Temple to the Mon Shwedagon Pagoda in Myanmar due to the influence of Mon Culture.

The same calendar system regarding the *Krittika* Full Moon Day as the NYE was also adopted by Sukhothai, a Thai Kingdom in the lower North during the thirteenth and fourteenth centuries, as written in the Royal books by King Li Thai (r. 1347–1368) of Sukhothai (Fine Arts Department, 2012) and by King Rama V (r. 1868–1910) of the Rattanakosin era (Chulalongkorn Rama V, 1920). The Sukhothai inscription describes the festivity on this day as filled with candlelight and loud firecrackers throughout the city. Similarly, Zhou Daguan, a Chinese diplomat monk who spent time in the Angkor capital city of Khmer in the late thirteenth century, also noted on this occasion that it was a New Year time when the city was decorated

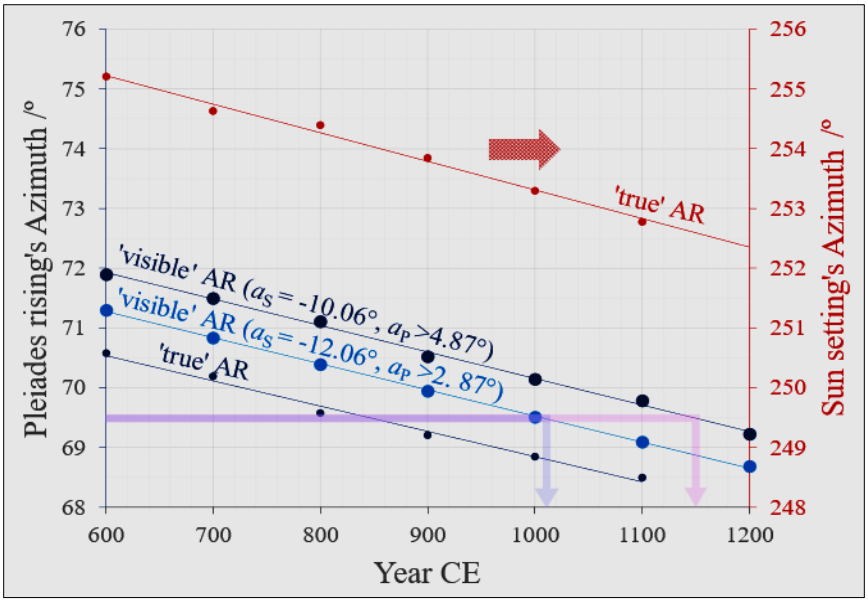

Figure 9: Azimuth angles of the AR of the Pleiades (y-axis on the left) versus time for the 'true' event (dotted black line) and the 'visible' events (dashed blue line and dashed black line are for lower bound and upper bound atmospheric conditions). The azimuth angles of the Sun for the 'true' AR events (y-axis on the right) versus time are indicated by the dotted red line.

with lanterns (Yongbungurd, 2000). It is reasonable to assume that a similar celebration would have taken place at Phimai Temple, and that fire-like objects were used to worship the God of Fire, *Agni*, the regent of the *Krittika Nakshatra*.

With the passage of time, the calendrical system was changed, and the significance of *Krittika* Full Moon Day as New Year's Eve faded from memory. In the present-day Thailand, people recognize the *Krittika* Full Moon Day as the Full Moon on the twelfth lunar month associated with the floating lantern festival, known as the infamous *Loy Krathong* festival. However, it is widely believed that the *Loy Krathong* festival originated from the ancient *Deevapali* ritual of India, which is a five-day ritual to worship the Hindu tri-gods around the *Krittika* New Moon Day, rather than the Full Moon Day; therefore, the common notion may be inaccurate. It is important that the cultural interpretation considers relevant astronomical events.

The calendar system that designates the *Krittika* Full Moon Day as the NYE is a lunar calendar. Since the lunar year is shorter than the tropical year, an intercalary month must be added to the lunar leap year to synchronize the lunar calendar to the seasons. Phimai Temple, which was designed to align with *Krittika* Full Moon Day, could have been used as an observatory for lunar leap-year notification, which would satisfy one purpose of the *Vastu Shastra* orientation as the place for the adjustment of the lunar and solar cycles. The Brahman lantern procession, which took place in Ayutthaya, a central Thai Kingdom that ruled from the fourteenth to the eighteenth centuries, is a custom that might reflect the notification of the lunar leap year with *Krittika*. To notify people of a lunar leap year so that they could adjust their agricultural activities accordingly, the officials would raise the lantern two weeks before the *Krittika* Full Moon Day, i.e., from the 1st Waxing Moon Day to the 2nd Waning Moon Day, a total of 17 days. If it was a normal year, the lantern would be raised only three days from the 14th Waxing Moon to the 1st Waning Moon (Chulalongkorn Rama V, 1920).

Considering the cultural significance of the Pleiades to the people of Phimai, it is highly possible that the acronychal rising (AR) of the Pleiades (i.e. the Pleiades rise as the Sun sets) around the *Krittika* lunar month in November may have been favored for the temple's orientation.

3.3 Dating Analysis of Phimai Temple

Archaeoastronomical and ethnoastronomical investigations suggest that the acronychal rising (AR) of the Pleiades related to the New Year's Eve of the Mon Calendar, and may have been used to orient Phimai Temple in accordance with *Vastu Shastra* principles. We obtained the azimuth of the AR of the Pleiades from Figure 7 and then traced back in time with precessionally-corrected Stellarium to yield the corresponding years. In Figure 9, the azimuth angles of the Pleiades and the Sun for the 'true' AR events are plotted over time. The 'true' event is the actual occurrence, which is difficult to observe because, as the Sun is on the horizon, its brightness washes out the sky, interfering with the star's observation. The difference between these two lines each year is approximately 184°–185°, which implies that the AR of the Pleiades can be observed on the Eastern horizon, inclining slightly Northward, opposite sunset. As can be seen from the graph, the 'true' AR of the Pleiades with the azimuth angle for an

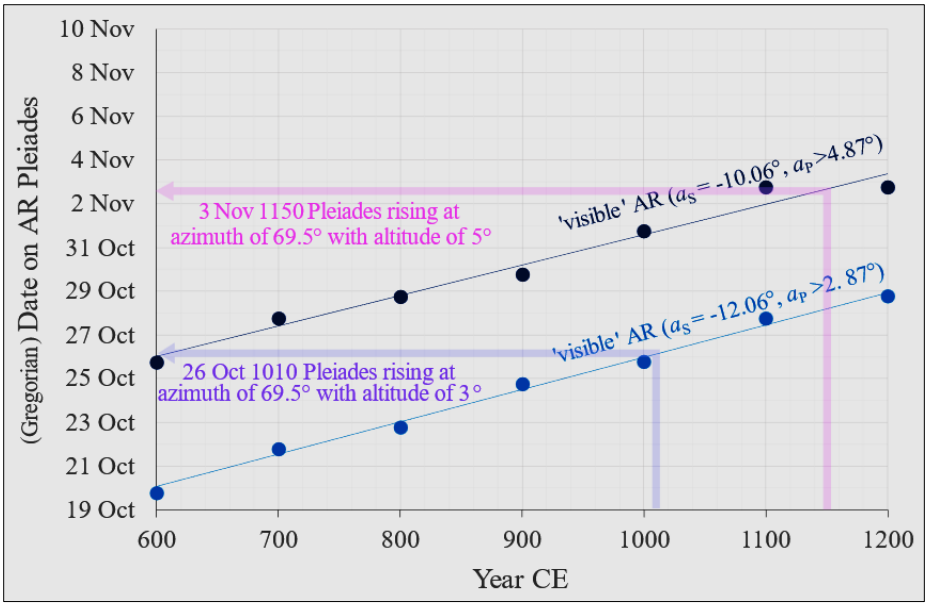

Figure 10: Gregorian dates for the 'visible' AR of the Pleiades versus time when they can be observed at the lower altitude of 3° (dashed blue line) and at the higher altitude of 5° (dashed black line).

orientation of 69.5° corresponds to the year 850 CE. However, supporting evidence relating to this year has yet to be found, which is understandable given the difficulty in observing a star during the 'true' event. A star is considered 'visible' for observation when the Sun merely dips below the horizon and the star is at least at its critical altitude of not being obscured by atmospheric extinction. Therefore, the 'visible' conditions with the Sun's *arcus visionis* (a_s) and the Pleiades' critical altitude (a_p) are considered in the Stellarium calculations. The Sun's *arcus visionis*, or the angle below the horizon that is inversely proportional to the brightness of the star being observed. Alcyone is the brightest star with a magnitude of 2.87 in the Pleiades cluster, which, according to a study by Schaffer (2000), corresponds to the *arcus visionis* of –12.06°. The critical altitude of the Pleiades is the same as the magnitude of the brightest star, i.e., 2.87°, based on the 'Rule of Thump' (*ibid.*). We use the 'visible' conditions regarding a_s = –12.06° and a_p = 2.87° as the lower bound conditions for the 'visible' AR of the Pleiades plot in Figure 9, and simply add 2° to these two parameters for the upper bound conditions, i.e., a_s and a_p become –10.06° and 4.87°, respectively. The corresponding years for the 'visible' AR of the Pleiades and the Phimai Temple alignment at 69.5° azimuth fall roughly between 1007 and 1147 CE.

We can also obtain the dates of the 'visible' AR Pleiades during the years 1007 and 1147 CE, as shown in Figure 10. During the possible years of orientation, the AR of the Pleiades can be observed between 26 October and 3 November, which corresponds to the *Krittika* lunar month and with the Sun in Scopious. The AR of the Pleiades dates fall between 26 and 28 October if the Pleiades are visible at a lower altitude of about 3°, and 1 to 3 November if they are visible at a higher altitude of about 5°. It should be noted that these 'visible' conditions assume a clear sky, and do not allow for atmospheric factors such as pressure, temperature, clouds or dust.

The period of 'visible' AR of the Pleiades between 1007 and 1147 CE coincides with the evidence found in the inscriptions mentioned in Section 1.2 (i.e., from the oldest Phimai Inscription (K.100) about the completed work by a sage, as well as from the Wat Chong Ko Inscription about the King Jayavirahvarman ordering a cadastral survey of the land in 1007 CE). King Jayavirahvarman remained on the throne in Angkor city from 1002 to 1006 CE before disappearing from Khmer records, and King Suryavarman I ascended the throne in 1006 CE. In 1007 CE King Jayavirahvarman's name appears in the Wat Chong Ko inscription at a temple near Phimai city, suggesting that he may have been living in exile in the Phimai area, where he may have supported the Phimai architect (possibly a Brahmin) who infused Mon Culture into building Phimai Temple as a Buddhist temple. When accompanied by the record of Phimai Inscription K. 953 (Princess Maha Chakri Sirindhorn Anthropology Centre, 2023d), which mentions the existence of the temple in 1035 CE, we can narrow down the possible years for the Pleiades orientation to 1007–1035 CE.

3.4 Phimai Temple's Entrance Explained by *Vastu Shastra* Principles

Our findings suggest that *Vastu Shastra* principles may have influenced the orientation of Phimai Temple, with the entrance to the temple

positioned in relation to the favorable star and its regent, which was the Pleiades (*Krittika*) and *Agni*. As a presiding deity in the *Vastu–purusha –mandala* depicted in Figure 2 (right) from the *Brihat Samhita* treatise, *Agni* was placed in the Northeastern corner. However, in later texts, *Agni* is replaced by the God *Isana* (another form of *Shiva*) and is assigned to the Southeastern corner instead, which coincides with his other role as the Lord of the Southeast direction, as shown in Figure 2 (right) (Kramrisch, 1976: 33). Based on our findings, the axis of orientation may have been established by the azimuthal axis of the Pleiades at 20.5° North of East during the *Krittika* Full Moon Day. The perpendicular axis was therefore 20.5° away from the South, towards the east. Locating the entrance of Phimai Temple on the orthogonal axis of *Krittika's* azimuthal axis would assume that the Temple faced the Southeasterly direction, protected by the worshipped god *Agni*.

4 CONCLUDING REMARKS

We employed archaeoastronomical surveying and ethnoastronomical analysis to investigate the astronomical wisdom embedded in the orientation of Prasat Hin Phimai, a Buddhist temple with a mix of Hinduism that was built in Northeast Thailand during the Khmer era. Phimai Temple, being built from Indian-based religious faiths with an oblique orientation, may have been aligned to a favorable star observed relative to the Sun on the horizon, conforming to the ancient Indian architectural science known as the *Vastu Shastra*.

Tracking stars at the temple back in time to correct for Earth's precession, we found that only the Pleiades (*Krittika* in Sanskrit) align with the Eastern Gate of the temple at approximately 69.5° azimuth or 20.5° off-East towards the North. The brightest star in the Pleiades is also the chief star of the *Krittika Nakshatra*, and ruled by Agni, the Lord of the Southeasterly direction. In addition to matching the orientation azimuth, *Krittika* also had cultural significance for the temple. Through traces of dates on Phimai inscriptions, we discovered that Phimai Temple adopted the Mon Calendar with the *Krittika* Full Moon Day as New Year's Eve, which was used by the Mon people, who were the previous inhabitants of Phimai before the Khmer domination. The celebration on this day involved candlelight, firecrackers and lanterns, which may have been used to worship *Agni*, the God of Fire and the ruler of the *Krittika Nakshatra*.

Therefore, *Krittika* Full Moon Day opposite the Sun in Scorpius may have been utilized as a favorable star to align the temple with, which corresponded to the acronychal rising (AR) of the Pleiades, when the Pleiades rose opposite sunset, as confirmed by the calculation of the 'true' AR of the Pleiades. By considering 'visible' criteria for the observation of the Pleiades and pertinent historical record, we dated construction of Phimai Temple to be 1007–1035 CE. We also suggested that King Jayavirahvarman may have been living in the Phimai area at this time and was a patron who supported the local Phimai architect in building Phimai Temple using *Vastu Shastra* principles. They chose *Krittika* when deciding on the axis of orientation of the temple, with *Agni*, the protecting deity of the temple. Note that this same configuration is also found in the Mon Shwedagon Pagoda in Myanmar.

As a result of the calendar system change, today in Thailand the *Krittika* Full Moon Day is recognized as the Full Moon on the 12th lunar month associated with the celebrated floating lantern festival, Loy Krathong.

The core concept of *Vastu Shastra* is to promote harmonious co-existence between mankind and the Universe by integrating astronomical wisdom into the design and construction of ancient sacred buildings and cities, many of which await study. Discovering the astronomical orientation of ancient structures can deepen our understanding of other cultural aspects, such as the ancient calendrical system and the origin and meaning of a tradition, and in the case of stellar orientation it allows dating analysis that makes use of precession.

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Dr. Cherdsak Saelee was born in Chiang Mai (Thailand) in 1970. He has BS (First Class Honours) and MS degrees from Chiang Mai University, and a PhD in Physics (in 1999) from Leeds University in the UK. Since 1995 he has worked as a lecturer in the Department of Physics and Materials Science at Chiang Mai University.

For more than two decades, he has been interested in archaeoastronomy as well as the Thai calendar, particularly in relation to Northern Thailand. His archaeoastronomical research is an extension of the research conducted by the late Associate Professor Samai Yodinthara, Assistant Professor Mullika Thavornathivas and Associate Professor Sanan Supasai, all three of whom had been researching and gathering information for more than 30 years. Cherdsak has collaborated with them since 1990 in three major areas: an outreach project to unify teaching and learning concepts for teachers and schools in Thailand; the relationship between the orientation of monastery temples and associated cultural traditions; and the Thai lunar calendar.

Orapin Riyaprao was born in Chiang Rai (Thailand) in 1976. She has a BS in Statistics from Chiang Mai University (Chiang Mai, Thailand) and an MA in Applied Mathematics from Long Island University (New York, USA). Currently she is a specialist and heads the History and Heritage of Astronomy group at the National Astronomical Research Institute of Thailand in Chiang Mai. Formerly she worked as a lecturer in the School of Science, Mae Fah Luang University in Chiang Rai, Thailand.

For more than one decade, Orapin's research interests have included Lanna and Thai historical records; the history of Indian, Chinese, Burmese and Thai calendars; temple orientations with respect to the azimuth of sunrise-sunset; and the wisdom of astronomy in Lanna Culture and its related kingdoms (i.e. the Kingdoms of Hariphunchai, Sukhothai, Ayutthaya, Lavo, Pagan, and Angkor).

Korakamon Sriboonrueang was born in Lamphun (Thailand) in 1979. He has a BEd in Physics from Chiang Mai Rajabhat University, Thailand and an MS in Teaching Physics from Chiang Mai University (Thailand).

He works with the History and Heritage of Astronomy group at the National Astronomical Research Institute of Thailand in Chiang Mai.

His research interests focus mainly on archaeoastronomy and ethnoastronomy, including the Lanna map of the lunar mansions and the application of the lunar mansions in daily life.

Assistant Professor Siramas Komonjinda has a BS (Physics) from Mahidol University, an MS (Physics) from Chiang Mai University and a PhD (Astronomy) from the University of Canterbury in New Zealand. She served as an Expert Advisor for the National Astronomical Research Institute of Thailand, and currently heads the Earth-Space Ecology research group at Chiang Mai University. Her research interests are in variable stars, binary star evolution, and exoplanet searches using both photometric and spectroscopic methods.

Siramas is also interested in archaeoastronomy, the history of astronomy, and calendars, especially those that relate to Thai culture and history. She is a member of Divisions C, F and G of the IAU, and is a former member of the Organizing Committees of IAU Commission C1 (Astronomy Education and Development) and Commission C4 (World Heritage and Astronomy).

Besides research, she is also very active in education and outreach activities in Thailand. At present, she is a member of the Organizing Committee of the International Olympiad on Astronomy and Astrophysics.

Dr. Prissana Thamboon was born in Chiang Mai (Thailand). She earned a BS (First Class Honors in Physics) from Chiang Mai University, an MS (Materials Science and Engineering) from The Ohio State University, and a

PhD (Applied Science and Engineering) from University of California at Davis in USA. After that, she conducted her postdoctoral training on femtosecond laser-matter interaction at Harvard University before returning to Thailand to teach Physics and Math at Mae Fah Luang University in Chiang Rai. She went on to work as a researcher, joining the relativistic electron beam research group at Chiang Mai University. She became a freelance writer and translator briefly before returning to Chiang Mai University as a researcher, first joining the Quantum Technology group and then the Archaeoastronomy group in 2023.

She has always been captivated by the science of luminaries and has developed an interest in multidisciplinary subjects since working as a freelance writer, which introduced her to archaeoastronomy. She had been studying the work of the Archaeoastronomy group and helping with manuscripts before finally joining the group, hoping to untangle and disseminate ancient astronomical wisdom to a broad audience.