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Research article

Archaeoastronomical Analysis of Sri Suphan Temple

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Abstract: Archaeoastronomical studies in the ancient Lanna Kingdom, centered in Chiang Mai Province in northern Thailand, have revealed the influence of *Vastu Shastra* principles, an ancient Indian treatise of architecture, on the alignments of cities and temples with auspicious stars. This paper investigates the orientation of Sri Suphan Temple, a royal Buddhist temple built in King Mueng Kaew's reign in 1503 during the Vaisakha lunar month, that has a similar orientation to the renowned Phra That Doi Suthep Temple, which was previously studied to be aligned with a star marking *Vaisakha* Nakshatra around 1537. We surveyed the site using a theodolite, a GPS device, and Stellarium astronomy software to yield the orientation of the temple with an azimuth angle of 58.94 ± 0.08°. Using precession-corrected Stellarium computation to trace stars' azimuths back in time and reveal their annual path behavior, we find Alphecca, with an azimuth of 59.45 degrees, rising on the eastern horizon during Vaisakha month as indicated in the inscription, to be the most probable star of alignment. Alphecca is a bright star in the Corona Borealis Constellation reported to be the same star used in the Doi Suthep Temple, which suggests that the Sri Suphan Temple may have been a prototype for aligning later Buddhist temples.

Keywords: Temple alignment; Stellar orientation; Sri Suphan Temple; Corona Borealis; *Vaisakha* Nakshatra

1. Introduction

Many archaeological sites around the world, including those in Italy [1], China [2], and Japan [3], have been discovered to align with astronomical phenomena connected to the Sun, Moon, classical planets, and stars, which can reflect the beliefs and culture of past civilizations. As a result, in archaeoastronomical investigation, the site's astronomical orientation should be concordant with historical data from written or unwritten sources, such as inscriptions, calendar systems, customs, and traditions [4–5]. For archaeoastronomical study in the ancient Lanna Kingdom, centered in Chiang Mai Province in northern Thailand, the founding of cities and temples may have been influenced by ancient Indian treatise of architecture known as *Vastu Shastra* principles, which was transmitted from India to Suvarnabhumi land through trade, migration, and religious dissemination since the Dvaravati and Khmer eras [6–7]. With its tenet of promoting auspiciousness connecting dwellings on earth with the universe, *Vastu Shastra* outlines the process and rituals from site selection to top structure completion [8]. According to *Vastu* principles, the orientation of the planned structure must be decided prior to construction. The primary consideration is the cosmic orientation with reference to the Sun, for example, an alignment that coincides with the rising or setting of an auspicious star during dawn or dusk, which is believed to be the time joining the earth and cosmos. The structure aligned with a star or stellar-oriented structure usually deviates noticeably from the cardinal directions, and the chosen star is often tied to indigenous identity. Dating of the stellar-orientated structure is also possible because the wobbling of the earth's axis causes precession of the equinoxes and thus stars to shift their positions from the past (roughly 1° in a century); if the star of alignment is known, its position can be traced back in time to estimate the founding year, and *vice versa*. Previous studies include the Chiang Mai city plan, which was aligned with Plough asterism (or Orion constellation), symbolizing fertility, and was dated to between 1292 and 1296 [9], whereas Phra That Doi Suthep Temple was orientated to Corona Borealis constellation, marking *Vaisakha* Nakshatra, and was dated to around 1537 [10]. It is possible that *Vastu* principles may have been used to build other Lanna sites.

Sri Suphan Temple, located in the silversmith neighborhood of modern-day Chiang Mai and well-known for its silvery-adorned exterior, was once a royal temple in the reign of King Mueng Kaew (*r*. 1495–1524), the 11th King of the Lanna founding dynasty, Mangrai [11]. According to the temple's inscription [12], the King authorized the construction of a Buddhist temple and named it Sri Suphan on 30 January 1501 Gregorian date, which is converted from Lanna calendar date [13, p.60]. The inscription also indicates that on an auspicious New Year's Day in Vaisakha or the 6th Thai lunar month, which is equivalent to 9 April 1503 Gregorian date (or 30 March in Julian date) [13, p.62], the Grand Vihara was founded. In the 1545 Chiang Mai earthquake, the Grand Vihara remained largely unaffected, indicating its orientation has been the same since its inception. The comparable orientation of the Grand Vihara to the renowned Doi Suthep Temple, as well as the inscribed remark of Vaisakha period on the founding day, imply that the Sri Suphan Temple may have also followed *Vastu Shastra* principles, using the same star for alignment as the Doi Suthep Temple. Therefore, in this work, we aim to analyze the stellar orientation of the Grand Vihara at the Sri Suphan Temple. We conducted an archaeoastronomical survey of Sri Suphan's Grand Vihara and utilized Stellarium simulated sky software to search possible stars of alignment during the period documented in the inscription. The results from this investigation help us better understand *Vastu Shastra*'s implementation in Lanna historical sites.

2. Materials and Methods

A conclusive archaeoastronomical analysis of the site's astronomical orientations requires consistency with traces of evidence, whether recorded or not, such as inscriptions, calendars, and traditions. The astronomical orientation of Sri Suphan Temple can be determined in two steps. The first step is to conduct a site survey using the archaeoastronomical approach described in Section 2.1 to estimate the azimuth angle of the temple. The azimuth is an angle measured clockwise from the North on the horizontal plane of the observer. The second step (Section 2.2) is to use Stellarium to calculate various stars' azimuth angles changing from the past and their annual rise or set behavior to identify possible stars of alignment that corroborate with the azimuth of the temple and the period mentioned in the inscription. Stellarium is the positional astronomy software package that calculates astronomical coordinates of celestial objects in the sky [5]. For this work, we use Stellarium version 24.2.0, a free GPL software that renders realistic skies in real time with OpenGL, and with ΔT correction using the default "Espenak and Meeus (2006)" model, accounting for atmospheric refraction and extinction, and a proper motion.

2.1 Archaeoastronomical Survey of Sri Suphan Temple

We employed the archaeoastronomical site survey technique, as detailed in Riyaprao et al (2023) [10], to determine the azimuth of the site by calibrating it against the known azimuths of Polaris and other bright stars, if feasible. While using multiple stars enhances the accuracy of the azimuth calibration, Polaris is particularly favorable because it remains nearly fixed in position, providing a reliable north direction. The selection of bright stars is practical, as they must be easily visible to a survey camera or theodolite within a vertical limit of 30 degrees. A yellow line in Figure 1 represents the orientation axis used to determine its azimuth angle of Sri Suphan Temple. A theodolite (Topcon, GTS-102N) was positioned at point A, facing towards point B along the yellow line, with horizontal angle reading was set to zero, establishing the line AB as the baseline equivalent to the temple's axis. A portable GPS device (Gamin, eTrex 32x) documented the theodolite's position as the observed location. Then, using the theodolite, we measured horizontal and vertical angles at different times of three bright stars: Polaris, Procyon, and Pollux. Readings for Polaris were taken every 5 minutes from 4:27 to 4:47 a.m., Procyon every minute from 4:51 to 4:57 a.m., and Pollux every minute between 5:00 and 5:08 a.m. We applied the least-squares method to calibrate the stars' measured angles with their respective azimuths and altitudes calculated by Stellarium, based on the observed location, date, and time. The offset value retrieved from the least-squares method is therefore the azimuth of the Sri Suphan Temple.

Figure 1. A satellite image of Sri Suphan Temple's Grand Vihara, with a yellow line indicating its axis. Points A and B are designated for a theodolite setup along the temple's axis. Map data: © OpenSteetMap contributors.

2.2 Stellarium computations of stars

The precession of the equinoxes, resulting from the wobbling of Earth's rotational axis, leads to a gradual shift in the ecliptic longitude of stars, thereby altering their azimuth angles over time. Stellarium simulates realistic skies, therefore their calculated positions are automatically precession corrected. Stellarium offers two types of calculated values: 'true' and 'apparent' values. For 'true' values, Stellarium requires only observed location, date, and time for input. For 'apparent' values, in addition to the required input, users can either use the default sky conditions or specify the observed sky conditions: Pressure, Temperature, and Extinction coefficient. The 'true' positions, as opposed to the 'apparent' ones, may not be directly observable due to the atmospheric conditions or the presence of the bright Sun, which can overwhelm the observation.

By employing precession-corrected Stellarium, we traced back in time the 'true' azimuth angle of various stars at the horizon, or zero altitude, to match with the azimuth of the temple. Stars falling within the temple's azimuthal range then underwent further analysis for their rising or setting patterns at the horizon in relation to the Sun to identify the star of orientation.

3. Results and Discussion

The parallelism of the baseline AB to the temple axis must be meticulously executed, as a misalignment of 1 cm can contribute to an angular error (Δθ) equal to $tan^{-1}(1\ cm/|\overline{AB}|)$. The longer baseline is preferable to minimize the angular error, but it is contingent on the accessibility of the site. For the Sri Suphan Temple, the $\overline{AB}$ length measures approximately 35 m, which could lead to an angular error of approximately 0.016 degrees for 1 cm deviation. The azimuth of the baseline, hence the temple's axis, is to be determined.

3.1 Sri Suphan Temple' s azimuth

Any bright stars visible at the Sri Suphan Temple on the survey day, in addition to Polaris, the North star, can be used to determine the azimuth angle of the temple's Grand Vihara. After setting the horizontal and vertical positions of a theodolite camera on the baseline to zero, the horizontal positions (Hr) and vertical positions (or altitude) of Polaris, Procyon, and Pollux were measured in succession. The altitude of Polaris changes very little over time, with only a 0.02° variation in 5 minutes. In contrast, the altitudes of Procyon and Pollux change by approximately 0.1° and 0.5° in 1 minute, respectively. The date (21st January 2024), the location (18.778500° N, 98.983336° E, Elevation 314 m), and the time of the theodolite measurement serve as inputs for Stellarium's calculation of the azimuths and altitudes of Polaris, Procyon, and Pollux, illustrated as lines in Figure 2. The green lines are 'true' values without atmospheric effect, whereas the redlines are 'apparent' values impacted by atmospheric conditions. The parameters entered for the atmospheric conditions are pressure of 977.32 mbar, temperature of 25°C, and extinction coefficient of 1. The extinction coefficient of 1 corresponds to an increase in a star's apparent magnitude (the star appears dimmer) by one order, which provides the best fit for our data as we observed during the winter dawn with fog affecting visibility. The Stellarium values accounted for atmospheric refraction, as seen by the red lines, resulting in a higher altitude than the green lines without atmospheric effect. The blue circle markers depict the calibration of the measured Hr data to the Stellarium (with atmosphere) line, which is achieved by adjusting Hr values with the 'offset' value derived from minimizing the squared residuals, also known as the least-squares method. The 'offset' value is therefore the azimuth of the baseline, which is equivalent to the temple's azimuth.

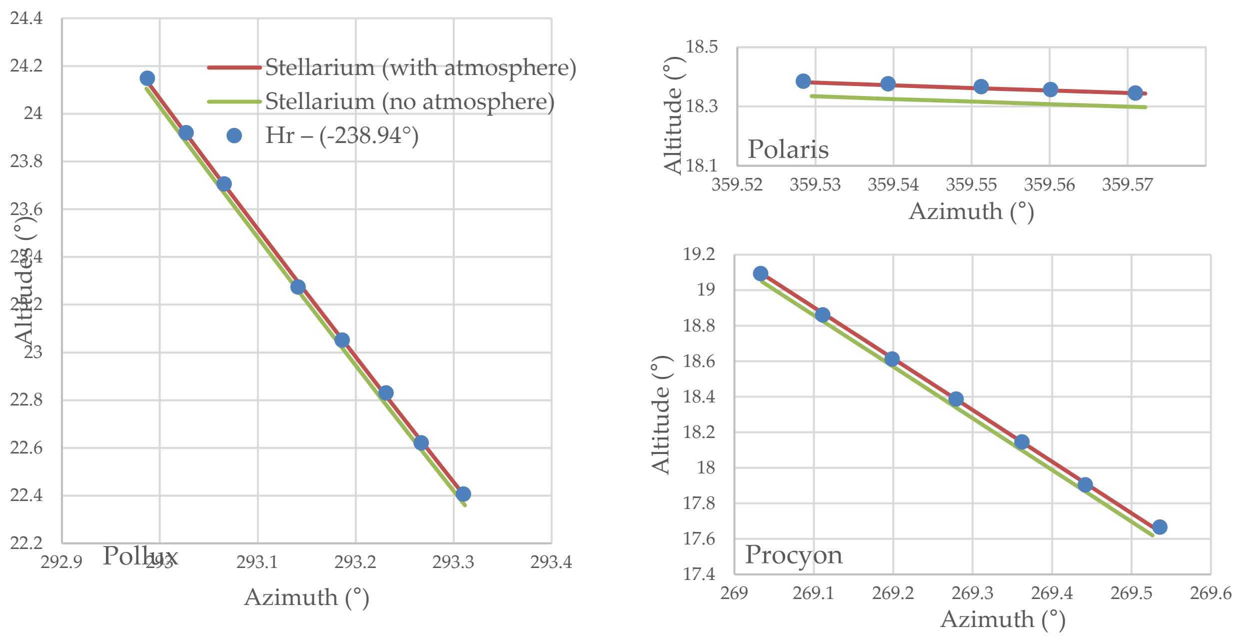

Figure 2. The altitudes and azimuths of Pollux, Polaris, and Procyon at the Sri Suphan Temple. In each graph, the red line is the computed Stellarium values with atmospheric conditions, whereas the green line is without. The blue circular markers represent the calibration of the measured Hr data to the Stellarium values of the stars.

The ‘offset’ values for Polaris, Procyon, and Pollux are 238.945°, 238.945°, and 238.939°, respectively, yielding an average of 238.943 ± 0.002° as the baseline’s azimuth. Since the baseline points towards the back or westerly of the Vihara, the easterly azimuth of the Vihara is calculated as 238.943 – 180 = 58.943°. If we restrict the misalignment in setting up the baseline to within 5 cm, the angular error would be 0.08° (5 cm × 0.016°/1cm), resulting in the final easterly azimuth of the Sri Suphan Temple being 58.94 ± 0.08°.

3.2 Identification of the star historically used for orienting the Sri Suphan Temple

According to the *Vastu Shastra* principles, the stellar orientation of a temple should be established during sunrise or sunset, as these moments are believed to connect the earth and the cosmos. We used precession-corrected Stellarium to trace back in time and calculate the ‘true’ azimuth at the horizon or at zero altitude for various well-known stars. Like the Doi Suthep Temple, the Sri Suphan Temple also lacks a star aligned with its westerly azimuth. The rising azimuth of a star on 1 January every 500 years is chosen to represent the azimuth trend plotted in Figure 3, serving as an initial screening for possible stars of alignment. The Sri Suphan Temple’s easterly azimuth and founding year of 1503 are overlaid in the graph, closely overlapping with azimuthal lines of Alphecca and Pollux. These two stars therefore could be utilized to set the temple’s orientation in the planning process prior to construction. Alphecca is a bright star in the constellation Corona Borealis, one of three asterisms representing *Vaisakha* Nakshatra, and known in Lanna as a winnowing basket’s rim star (Thai: ดาวขอบดั้ง). Pollux is a bright star in the constellation Gemini, representing *Punavarsu* Nakshatra, and recognized in Lanna as the Golden Chinese Junk Boat.

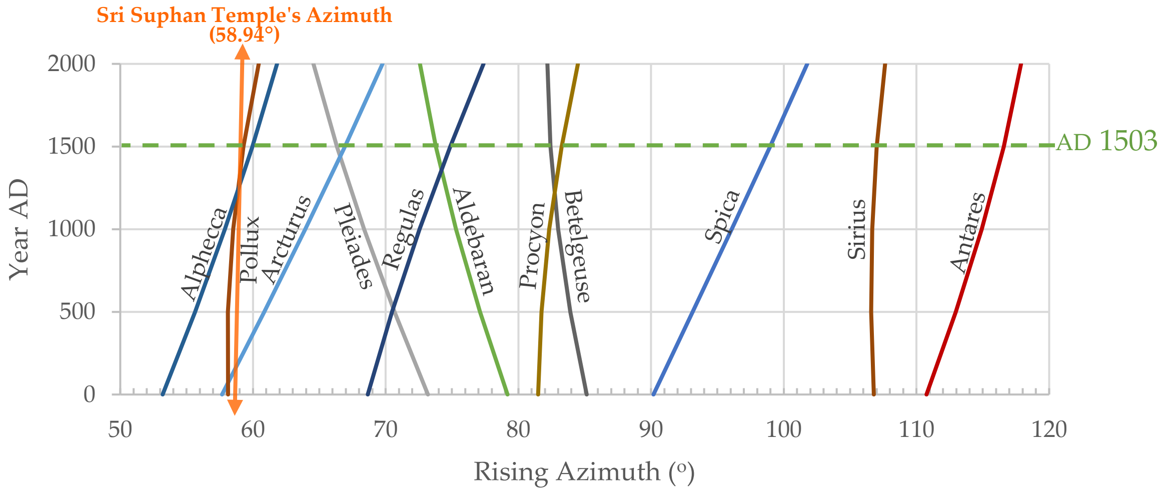

Figure 3. Rising azimuth trends tracing back in time for various well-known stars. The orange arrow locates the Sri Suphan Temple’s azimuth. The dashed line indicates the founding year of the Grand Vihara.

To further identify which one is the lone star of orientation, we examine the rising behaviors of both Pollux and Alphecca during the temple’s founding year, as indicated in the inscription. A star rises and sets four minutes earlier on subsequent nights, leading to four rising and setting behaviors in relation to the Sun each year, as defined in Table 1. The cosmical phenomena occur at dawn with respect to sunrise, whereas the achronycal phenomena in relation to sunset take place at dusk. In other words, these four astronomical events signify four types of stellar orientation based on the cosmic orientation rules of *Vastu Shastra* principles.

Table 1. Rising and setting behaviors of a star with respect to the Sun.

	With the star	Opposite the star
Sunrise at dawn	Cosmical rising (observable heliacal rising)	Cosmical setting
Sunset at dusk	Achronycal setting (observable heliacal setting)	Achronycal rising

Since we focus on the stars aligned to the east side of the temple, we plot the rising times of both Alphecca and Pollux, using the 'true' rising azimuths from Stellarium, along with sunrise and sunset times during 1503 AD in Figure 4. As indicated in the graph, the achronycal rising (AR) event refers to a star crossing the eastern horizon as the Sun sets; it is the last day a star seen rising after sunset. The cosmical rising (CS) event, on the other hand, refers to a star crossing the eastern horizon as the Sun rises; the observable one is called the heliacal rising when a star appears briefly just before the overwhelming light of sunrise. The AR and CS events of Pollux and Alphecca, as indicated in the graph, were the possible alignment times. However, only the AR of Alphecca coincided with the founding period of the Grand Vihara during the Vaisakha lunar month as noted in the inscription, which was around April to May. Hence, the star that may have been used to align the Sri Suphan Temple (azimuth ≅ 58.94°) in 1503 AD is Alphecca (azimuth ≅ 59.5°), a bright star in the constellation Corona Borealis. In Lanna, the presence of Corona Borealis with the full moon marks the Vaisakha lunar month. The full moon in Vaisakha month is known in Southeast Asia as Vaisakha Puja Day or Vesak, the Buddhist holy day commemorating the birth, enlightenment, and death of the Buddha.

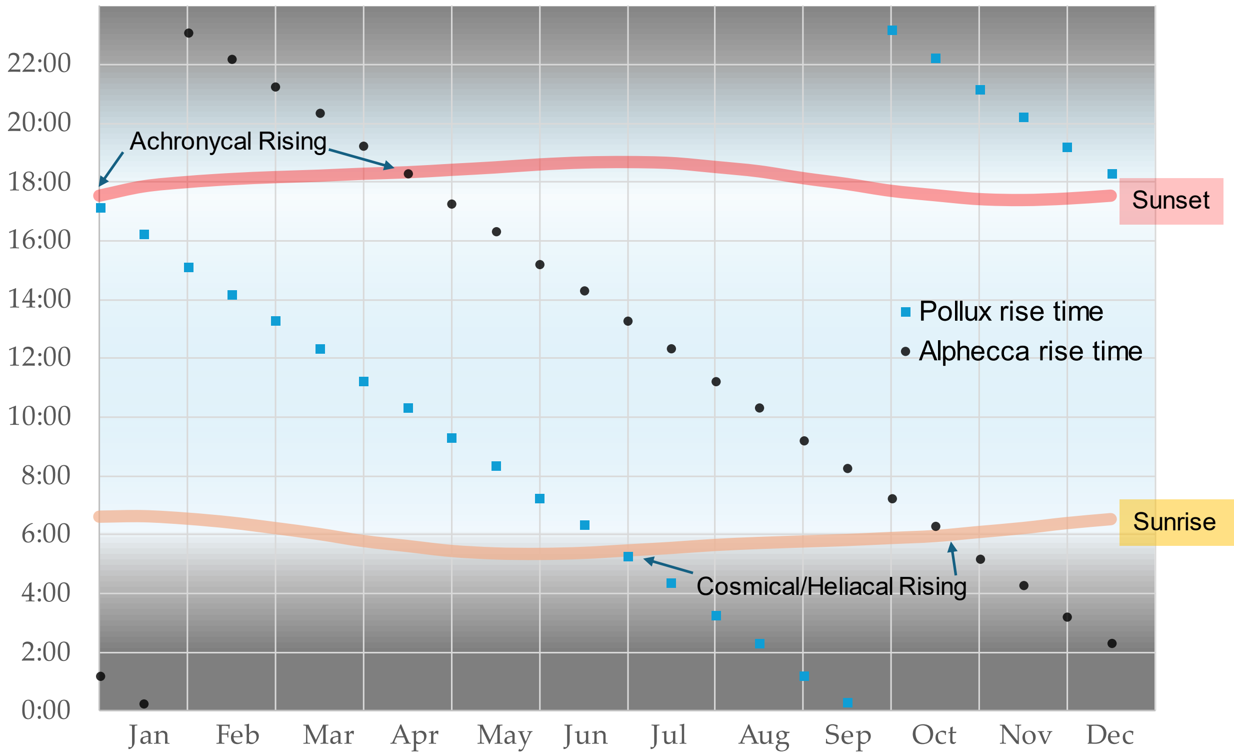

Figure 4. Rising times of Pollux (the blue squares) and Alphecca (the black dots), including sunrise and sunset times, as calculated by Stellarium for the year 1503.

3.3 Astronomical events documented on the inscription

One advantage of archaeoastronomical analysis is its ability to date an ancient site that was stellar oriented. However, it should be noted that the estimated date conveys when the stellar alignment was executed to establish the site plan, the ritual diagram *Vastu-Purusha-Mandala*, on leveled, purified ground. The germination rite, symbolized the inception of the site, was then performed, constituting a 'forecast' at the birth of the site [8]. The extent to which this process was strictly followed and how reliably it translated into the founding date noted in the inscription remains unknown. By comparing astronomical events recorded in the inscription with Stellarium simulated sky, we can gain a better understanding of how the Vastu Shastra principles were implemented in the Lanna tradition. Since Stellarium uses Julian dates to simulate the ancient sky prior to 15 October 1582, the date that signifies the transition from the Julian to the Gregorian calendar, the dates in the Sri Suphan Inscription must first be converted to Julian dates before being checked with Stellarium.

We focused on the Vihara's founding date, which corresponds to 9 April 1503 in the Gregorian calendar and converts to 30 March 1503 in the Julian calendar [12]. This date is specified in three calendar systems: *Culasakaraj*, *Buddhist Nirvana Era*, and *Hontai*, as adopted in the Lanna Kingdom. In Figure 5, we present a timeline of the astronomical events recorded in and inferred from the Sri Suphan Inscription on the left side, comparing it with Stellarium simulated sky on the right side. According to the inscription, the founding date was the auspicious New Year's Day in the *Culasakaraj* lunisolar calendar, marking the moment when Sun crosses into *Mesha Rasi* (Aries). This date was determined through calculations based on the Suriyayatra treatise. Although the event itself is unobservable, the ancient practice involved marking this day with Spica, the star opposite Aries along the ecliptic, which sets at sunrise. In Thailand, the temple that may align with the New Year's Day in the *Culasakaraj* calendar using Spica is Prasat Hin Phanom Rung, which has an azimuth close to 90 degrees [14]. In the case of Sri Suphan Temple, this date appears to have been chosen only for founding the temple, and it is consistent with the Stellarium simulated sky, which reveals Spica setting around 6 a.m. The founding day was also the 4^{th} waxing moon day in the *Buddhist Nirvana Era* lunar calendar; however, it differed slightly in the Stellarium, which indicated a moon age of 3.2 days (waxing moon). As a result, we can infer from the inscription that the full moon (15^{th} waxing moon day) occurred on 10 April 1503, while it was 11 April 1503 for the Stellarium simulation. The full moon near Vaisakha star, Corona Borealis, also known as Vaisakha Puja Day (Vesak), is regarded as New Year's Day in the *Buddhist Nirvana Era*. Many ancient temples were aligned with stars marking calendrical New Year's Day. Sri Suphan Temple is a Buddhist temple that was aligned with the Vaisakha star, Corona Borealis; yet it was founded on the New Year's Day in the *Culasakaraj* calendar instead, which came before the Vesak. This implies that the alignment star must comply with Vastu principles, but the alignment date may be flexible. Figure 4 shows Alphecca rising in the evening until mid-April, and as the alignment procedure should be completed before the founding date of 30 March 1503, preceding evenings are possible temple alignment dates. An example of alignment event is shown in Figure 6 on the evening of 29 March 1503, with Alphecca rising on the eastern horizon at 19:32 hours, when the Sun had already fallen 18° below the horizon in the astronomical twilight. This scenario is more feasible for star observation than the ideal alignment time around 15-17 April 1503, which indicated the achronycal rising of Alphecca.

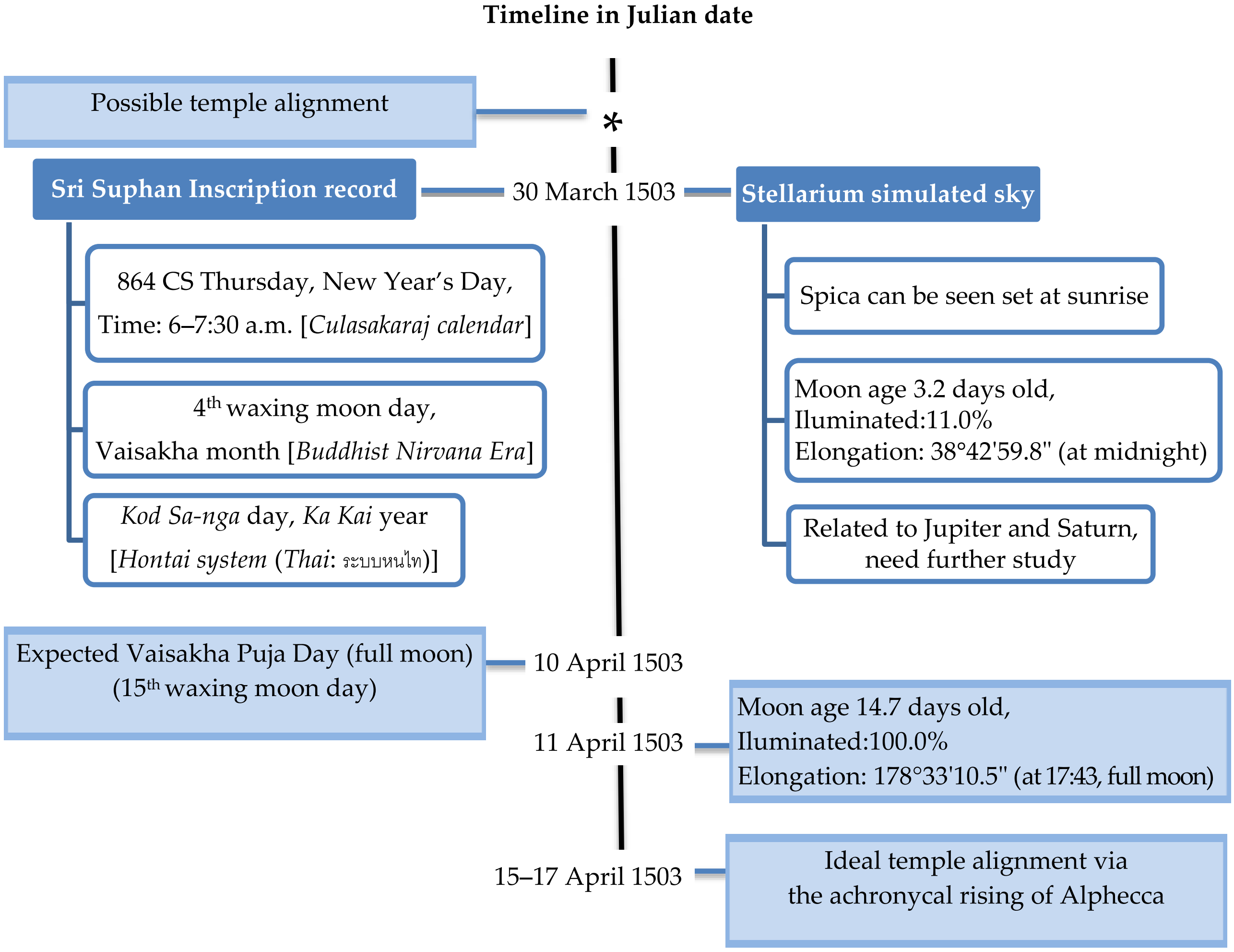

Figure 5. Timeline in Julian dates of the astronomical events excerpts from the Sri Suphan Inscription (on the left) and the Stellarium simulated sky (on the right).

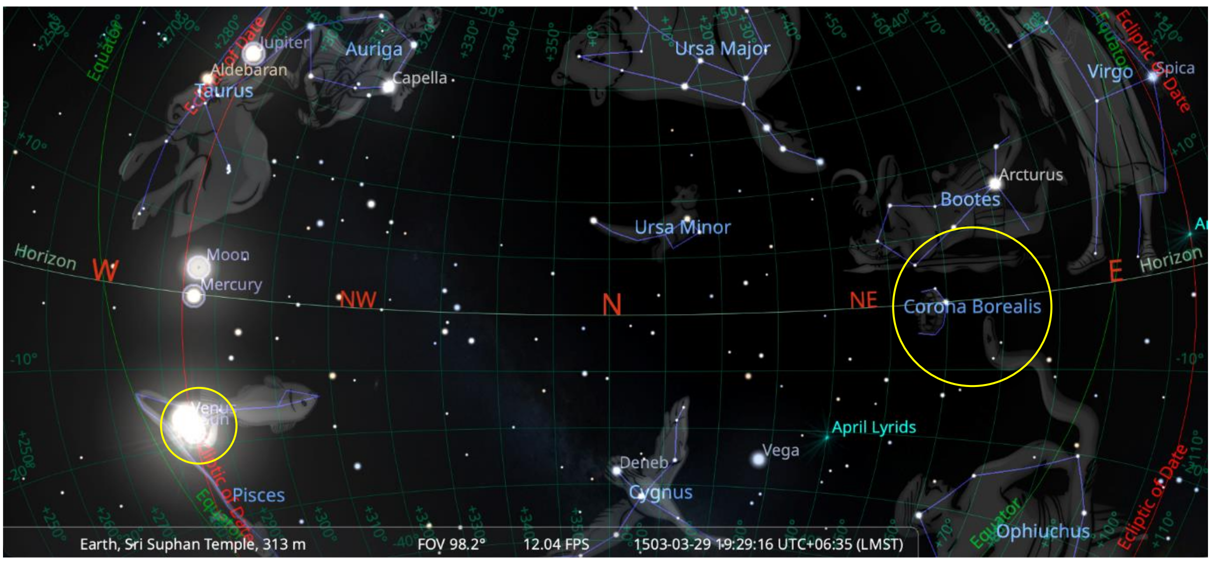

Figure 6. Stellarium simulated sky showing relative positions of Alphecca and the Sun (circled in yellow; Alphecca on the horizon, but the Sun was about 18° below the horizon at 19:32 on 29 March 1503) that could be used for the Sri Suphan Temple's alignment.

The Sri Suphan Temple and the renowned Phra That Doi Suthep Temple, two Buddhist temples built in succession in the same era, both employed the same alignment method using Alphecca in the constellation Corona Borealis, which may suggest that *Vastu Shastra* principles were widely implemented in the Lanna Kingdom, and the Sri Suphan Temple may have served as a prototype for orienting later Buddhist temples to be associated with the Vaisakha lunar month. The tradition of modern-day Buddhist temples in Chiang Mai erecting a vihara or Buddha image during Vaisakha Puja Day indicates that the preference for Vaisakha month remains, but the orientation rule has faded away with time.

Archaeoastronomical analysis possess a multi-disciplinary nature. Modern astronomy software, such as Stellarium, can be used to examine the ancient sky, but it requires traces of historical evidence to solidify its findings. Ethnoastronomy, which includes knowledge of the stars and the calendar systems of different ethnic groups, is also essential. Furthermore, even non-written traditions might contribute to the analysis. Some archeological sites might have all evidence we need, but some others might lack one or more. It is important that we continue to explore more sites to allow us to detect patterns and be able to elucidate one to another, hence filling in the missing puzzles of the ancient world.

4. Conclusions

The archaeoastronomical analysis of the Sri Suphan Temple with a measured azimuth of 58.94 ± 0.08° reveals that it is closely aligned with Alphecca, a bright star in constellation Corona Borealis. The finding agrees with the inscription record that the temple was founded during the Vaisakha lunar month, which is marked by Corona Borealis and the full moon. However, the founding date, which is converted to 30 March 1503 Julian date, was New Year's Day in the *Culasakaraj* lunisolar calendar, which was before Vaisakha Puja Day, New Year's Day in the Buddhist Nirvana Era lunar calendar, and the achronycal rising of Alphecca. According to *Vastu Shastra* principles, the stellar alignment must be accomplished prior to the founding date, which leads to a possible alignment date of the preceding evening of 29 March 1503 Julian date, when Corona Borealis was still visible on the horizon. The orientation resembles the Phra That Doi Suthep Temple of a later Buddhist temple, implying that alignment knowledge was passed down from the Sri Suphan Temple.

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