Journal of Astronomical History and Heritage, 26(1), 31–68 (2023).

THE ROLE OF TEMPORARY WESTERN OBSERVATORIES IN THE DEVELOPMENT OF PROFESSIONAL ASTRONOMY IN THAILAND

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Abstract: During the nineteenth century Siam (present-day Thailand) was trapped between British colonies to the west (Burma) and south (the Straits Settlements) and a French colony to the east (Cochin China), yet managed to retain its independence—the only SE Asian nation that succeeded in doing so.

One consequence of this was that Siam did not establish a National Observatory or network of regional observatories, which were a conspicuous element of British colonialism (as witnessed, for example, in Australia, India and South Africa). Despite their designations as 'astronomical observatories', the primary function of these institutions was to provide a regulated local time service and meteorological data, but some also were involved in geomagnetic research, seismology, trigonometrical surveys and astronomical research. In Siam/Thailand, these non-astronomical functions were pursued by different Government departments or instrumentalities.

Instead, Siam witnessed its first 'modern' astronomical observatories when European expeditions accepted invitations to come to Siam to observe the total solar eclipses of 1868, 1875 and 1929. These expeditions led to the emergence of academic astronomy in Thailand and the establishment of the nation's first permanent astronomical research observatory.

In this paper, after reviewing British colonial observatory role models we will examine the nature of Siamese astronomy during the nineteenth century, the 1868, 1875 and 1929 European eclipse expeditions, and the subsequent development of professional astronomy in Siam. This culminated in the establishment of the National Astronomical Research Institute of Thailand in 2009 and the phenomenal growth of astronomy during the following decade, primarily under strong Royal patronage.

Keywords: Siam/Thailand, astronomical observatories, solar eclipses, King Rama IV, King Rama V, Chulalongkorn University, National Astronomical Research Institute of Thailand

1 INTRODUCTION

This paper is about the historical development of astronomy in Siam (present-day Thailand) and the emergence of professional astronomical observatories. In Siam, there was a long tradition of Royal patronage of astrology, but King Narai (1633–1688) was the first Emperor to carefully differentiate astrology from Western-style 'scientific' astronomy and foster an interest in and develop some understanding of the latter (e.g. see Gislén et al., 2018; Orchiston et al., 2016; 2021a; 2021d). In 1685 King Narai's patronage led to the construction of Wat San Paulo, which included an impressive 4-storey tower observatory (Figure 1) that we believe was inspired by the design of part of Paris Observatory (Orchiston et al., 2022). This was the first astronomical observatory to be built in Siam, but its demise followed the premature death of King Narai in July 1688, and today only the hexagonal foundations of the observatory remain, along with sections of two of the walls.

As Ôhashi and Orchiston (2021: 743) point out,

> The Spanish had colonial ambitions in the Philippines archipelago and the Dutch in what is now Indonesia from the sixteenth century, in competition mainly with the British and the Portuguese, while the French tended to focus on mainland Southeast Asia … The United States of America came later … All of these colonising nations were inspired by commercial opportunities, international status and prestige, and also in the case of the Philippines the desire by Catholic priests to win religious converts (see Hall, 1981).

During the nineteenth century Siam was threatened by the British who occupied India and Burma to the west and the Straits Settlements to the south, and the French who were who were in Indochina to the east (see Figure 2; Chandran, 1977). Both of these European

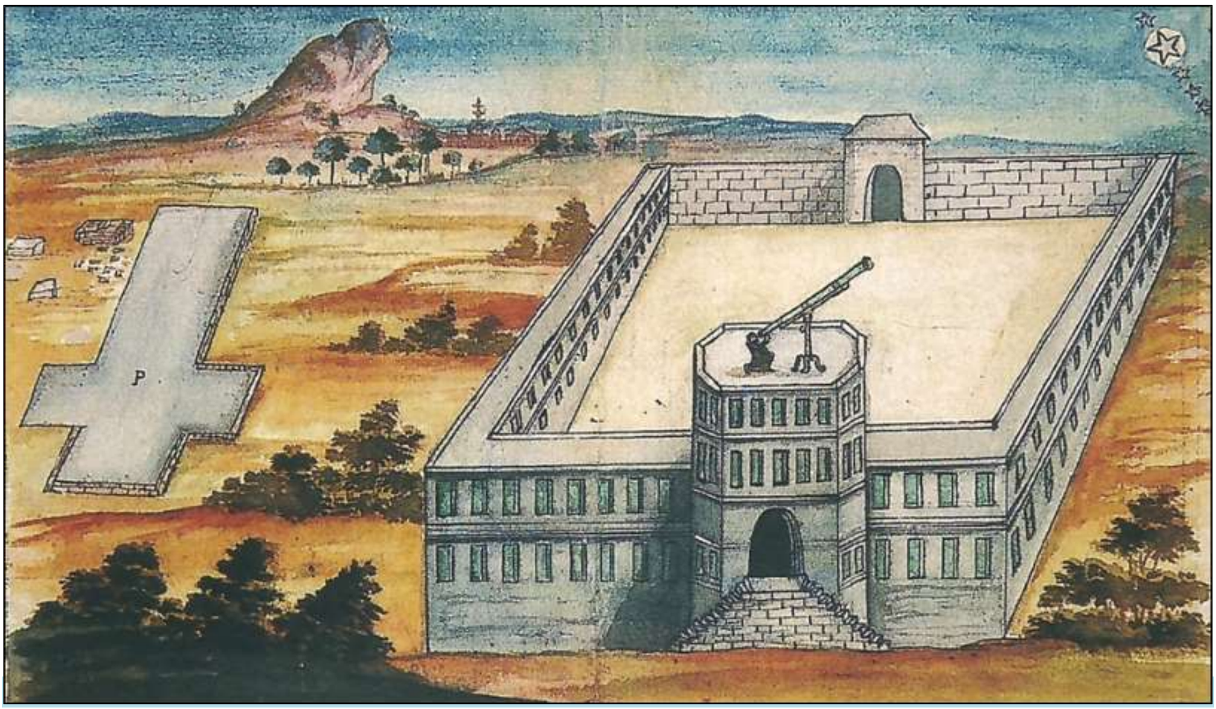


Figure 1: A contemporary painting of Wat San Paulo, with its distinctive 4-storey tower observatory (Wikimedia Commons).

nations established astronomical observatories as part of their colonial enterprises, but independent Siam did not. Instead, it was total solar eclipses that attracted Western expeditions to Siam in 1868, 1875 and 1929, and these events provided the launching pad for academic and professional astronomy to emerge and ultimately prosper in Siam and Thailand (as the nation was renamed, in 1939).

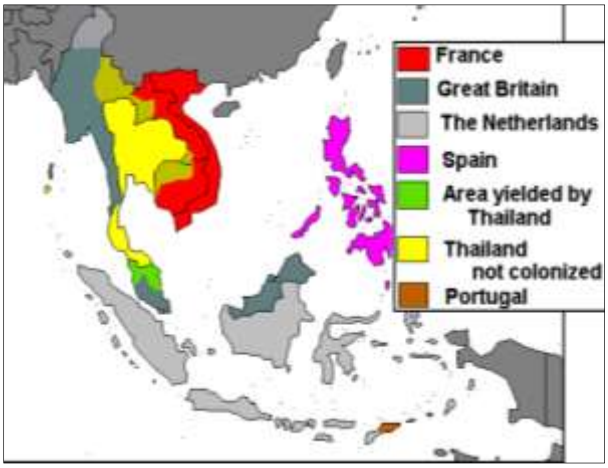


Figure 2: A map of nineteenth century SE Asia showing colonial affiliations. Key. France: Indochina; Great Britain: Burma, Malaya, Sarawak, British North Borneo; The Netherlands: Dutch East Indies; Spain/USA: Philippines; Portugal: Timor. Only Siam/ Thailand remained independent, although it was obliged to cede territory to France and to Britain (map: https://sites.google.com/site/resourceguidetoimperialism/imperialism-in-south-east-asia).

In this paper we will briefly review the characteristics of nineteenth century British observatories, before documenting how Siam accommodated the need for national time and meteorological services and a trigonometrical survey capability during the second half of the nineteenth century in the absence of a national observatory. This fact, and Royal support for astronomy, were key factors in the nature of astronomical development in Siam/Thailand during the nineteenth and twentieth centuries.

2 NINETEENTH CENTURY PROFESSIONAL OBSERVATORIES: ASIAN-OCEANIC COLONIAL ROLE MODELS

As the title suggests, the conference on "Where Science and Empire Met: Observatories in Asia in the Late 19th to Mid–20th Centuries" examined the relationship between colonialism and the development of astronomical observatories in Asia during the second half of the nineteenth century and first half of the twentieth century. Great Britain and France both had long traditions of professional astronomy (see Forbes, et al., 1975; Bobis and Lequeux, 2012, respectively), with Australia serving as an excellent role model of the way in which professional astronomy could be developed in the British colonies.

Between 1840 and 1896 nine professional observatories were established in the different Australian colonies. Their geographical distri-

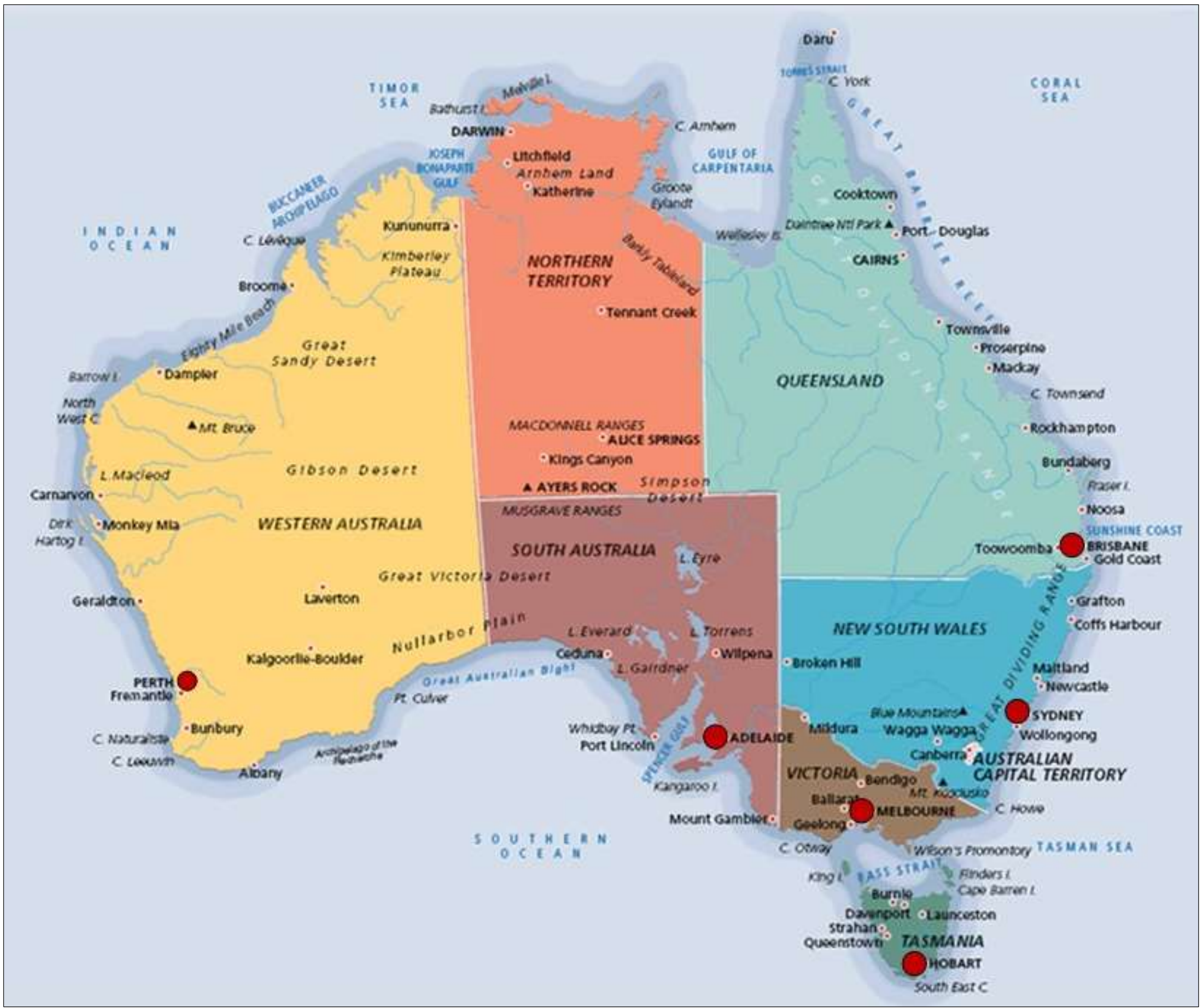


Figure 3: Locations of Australian professional observatories founded between 1840 and 1896 (map modifications: Wayne Orchiston).

bution is shown in Figure 3, and their foundation dates, major astronomical instruments and functions are summarized in Table 1. Note that Williamstown and Flagstaff Observatories were closed down and their functions combined when Melbourne Observatory was founded. In addition to the observatories listed in Table 1, the Jesuits founded Riverview Observatory in Sydney in 1909 (Orchiston, 1985a), which initially was devoted solely to seismology (O'Connell, 1952).

While all of the institutions listed in Table 1 were categorized as 'astronomical' observatories, there were only two functional common denominators: time-keeping and meteorology. Time-keeping was understandable given the avalanche of immigrants arriving in Australian ports in the nineteenth century (but particularly Melbourne and Sydney, with the lure of the goldfields) and the need for ships' officers to regulate their chronometers. This was best achieved by making meridian observations of selected 'clock stars' with a transit telescope (see Figure 4) linked to a master astronomical clock, and then using a time ball which was dropped daily (typically at noon) to indicate the time. Figure 5 shows Sydney Observatory with its tower and time ball. Whilst present worldwide, the time ball concept originated in Britain, which is why they were found in India, Australia and New Zealand, and in British colonies in SE Asia (see Kinns 2009; 2011; 2017; 2020; 2021; 2022; Kinns and Abell, 2009).

Meteorology was the other primary function of all of the observatories listed in Table 1 and the justification for this is succinctly stated by Sir Charles Todd (1893), Director of Adelaide Observatory:

> That meteorology should have been taken up so energetically [in Australia] and been so liberally supported by the several Colonial Governments, on whose purse, in building up a new nation, there are many claims, is not, however, without a sufficient cause. To successfully occupy and establish

Table 1: Australian professional observatories, founded 1840–1896 (after Orchiston, 2016: Table 3.1).

Observatory	Founding Year	Main Telescope(s)*	Main Functions	Reference(s)
Rossbank (Hobart)	1840	-----	Time service Meteorology Geomagnetism	Savours and McConnell, 1982.
Williamstown (Melbourne)	1853	4.5-in OG	Time service Meteorology Astronomy	Andropoulos, 2014; Ellery, 1869.
Flagstaff (Melbourne)	1858	Small OG	Meteorology Geomagnetism	Neumayer, 1858; Weiderkehr, 1988.
Melbourne	1863	48-in spec 8-in OG 13-in astr	Time service Meteorology Astronomy Geomagnetism	Andropoulos, 2014; Gascoigne, 1992; Gillespie 2011; Perdrix, 1961.
Sydney	1858	11.5-in OG 7.25-in OG 13-in astr	Time service Meteorology Astronomy	Lomb, 2011; Orchiston, 1988a; Wood, 1958.
Adelaide	1874	8-in OG	Time service Meteorology Astronomy	Edwards, 1993; 1994.
Brisbane	1879	Small OG Small tran	Time service Meteorology	Haynes et al., 1993.
Hobart	1882	Small tran	Time service Meteorology	Anonymous, 1900.
Perth	1896	12-in spec 13-in astr	Time service Meteorology Astronomy	Hutchison, 1980; 1981; Utting, 1989; 1992.

* Key: astr = astrograph; OG = refractor; spec = reflector; tran = transit telescope

> industries in new countries, a knowledge of climate and meteorological conditions under which we are to labour is essential to success ...

Mindful of the expansion of farming activities throughout the continent, all of the Australian observatories worked assiduously to establish meteorological recording stations in their respective colonies. For example, between his arrival in 1856 and the end of 1861 founding Director of Sydney Observatory Reverend William Scott (1825–1917) established 13 country meteorological stations (Orchiston, 1998: 34), while later Director, Henry Russell (1836–1907), began in 1870 with 55 and by 1891 there were no less than 1,238 (Orchiston, 1988a: 54), scattered throughout New South Wales. Russell conducted research and published research papers on meteorology, and in 1877 he began issuing daily weather maps (*ibid.*). All this changed dramatically in 1908, after Australian federation, when meteorology was withdrawn from the State Observatories and

> … centralised under the banner of the newly-formed Commonwealth Bureau of Meteorology … [but] This was a 'two-edge sword', for although it left more time free for astronomy it also was accompanied in most instances by the almost inevitable funding cuts. (Orchiston, 2016: 88–89).

In the nineteenth century, India also had a network of astronomical observatories (see Ansari 2000; 2011; Kapoor and Orchiston, 2023a; 2023b; Kochhar and Orchiston, 2017), and while their meteorological efforts also focused on agriculture, hence on rainfall, floods and droughts, their interest was more

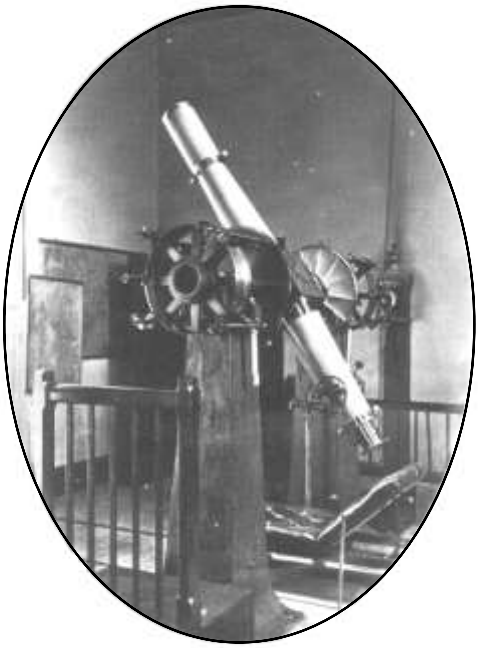


Figure 4: The Sydney Observatory transit telescope (photograph courtesy: Harley Wood).

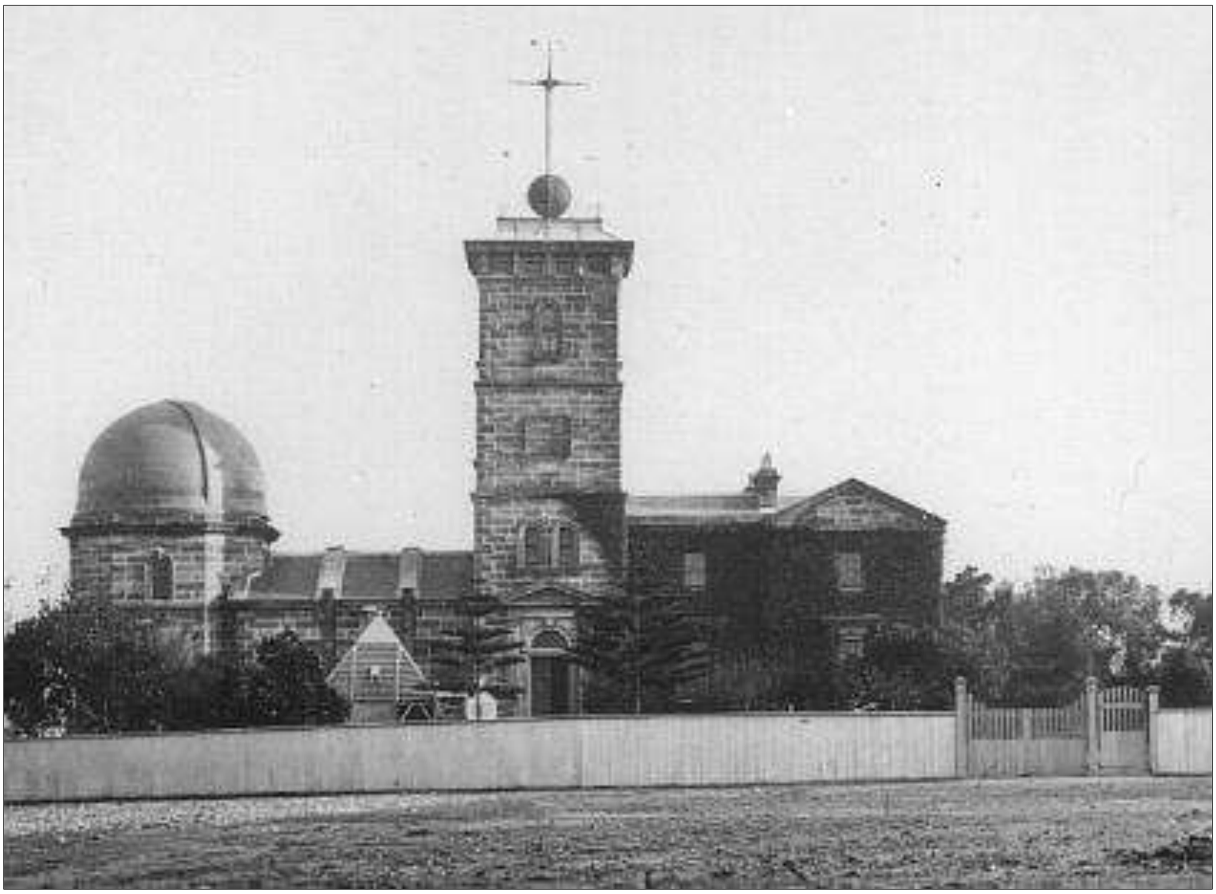


Figure 5: Sydney Observatory in the 1870s, with (from left to right) the dome housing the 11.5-inch refractor, the transit telescopes room, the central tower with the time ball, and the residence of the Government Astronomer. In 1880 a stand-alone dome was erected just inside and to the right of the entrance gate, which eventually housed the 13-inch astrograph (photograph courtesy: Harley Wood).

in the onset and intensity monsoons. Meanwhile, the astronomers at Manila Observatory in the Philippines (Alvarez, 2020; Cushman, 2013; Seitzer, 2020; Warren, 2009) and Central Indochina Observatory in Vietnam (Phạm and Lê, 2021; Phuong, 2023) also paid close attention to the monsoons, but they were even more concerned about cyclones, which were characteristic of this particular region of SE Asia (Warren, 2012; Williamson and Wilkinson, 2017). Although

> … they occurred during specific seasons (i.e., 70% within the four consecutive months from July to October; see García Herrera et al., 2007: Fig. 4), the occurrence of individual cyclones could not be predicted, and their impact on human lives and on habitat often was (and continues to be) disastrous. Cyclones also usually are associated with torrential rainfall, leading to floods and landslides. (Orchiston et al., 2021: 49–50).

So cyclones not only impacted on agriculture in a major way, but they also could lead to widespread destruction and loss of human life, and could influence the economy for years to come.

Of the Australian observatories listed in Table 1, only Williamstown, Sydney, Melbourne, Adelaide and Perth conducted astronomical research *per se* (Orchiston, 2017; Orchiston et al., 2017). In addition, some of these major observatories at one time or another also engaged in geomagnetic research and trigonometrical surveys. These last-mentioned surveys were major time-consuming and manpower-intensive enterprises, yet vital, as they alone could delineate colonial boundaries within the Australian island continent, or national boundaries in mainland South and SE Asia. Thus, both Sydney and Melbourne Observatories soon handed over their trigonometrical survey responsibilities to the respective Lands Departments (Orchiston, 2017), while in India Madras Observatory also relinquished its geodetic survey to the Survey Department, which then initiated the 'Great Trigonometrical Survey of India' (Phillimore, 1945–1968). Kochhar and Orchiston (2017: 715) described this as

Figure 6: The old Perth Observatory main building, which is now the headquarters of the National Trust of WA (courtesy: westaussieweddding.typad.com).

> …a monumental scientific endeavour, unparalleled in the world by virtue of its vastness … and logistical problems … It took precedence over all other surveys in India and was equipped with the best of manpower and equipment …

But as Roy (1986 307) points out, the Great Trigonometrical Survey of India was a purely colonial enterprise, carried out so that the British would have accurate geographic data and maps for military and administrative purposes, and also in order to collect taxes. Kochhar (1991: 128) would go further and maintain that

> Modern science [including astronomy] in India was a utility: its function was to help the British manage their colony in a profitable and efficient manner. Any benefit to science itself was unintended and secondary.

Like trigonometrical surveys, geomagnetic studies were another field that was soon jettisoned by those astronomical observatories that attempted them. It was only in the nineteenth century that a worldwide 'geomagnetic crusade' (Cawood, 1977) was launched by the Irish scientist and explorer Edward (later Sir Edward) Sabine (1788–1883). His vision was to investigate variations in the Earth's magnetic field by establishing dedicated geomagnetic observatories throughout the British Empire or encouraging astronomical observatories to participate in geomagnetic research. In Australia, Rossbank Observatory in Hobart (Tasmania) existed from 1840 to 1854 (Savours and McConnell, 1982), and—as we have seen —when Flagstaff Observatory in Melbourne was closed down, its geomagnetic research was transferred to Melbourne Observatory, only to move again in 1919 to a new dedicated geomagnetic facility at Toolangi Observatory near Melbourne (McGregor, 1979). Partly because of its closer proximity to the Equator, geomagnetic research tended to fare better in India, and at one time or another was carried out at Colaba, Kodaikanal, Madras, Sabhawala, Simla and Trivandrum Observatories (e.g. see Rastogi, 1986; Ratcliff, 2016). All but Kodaikanal and Madras were, or ended up being, dedicated geomagnetic observatories, revealing India's commitment to the international 'geomagnetic crusade'.

All of the major Australian astronomical observatories featured imposing-looking main buildings (e.g. see Figures 5 and 6), with non-meridian telescopes housed in hemispherical or drum-shaped domes. Some of these non-meridian instruments were in stand-alone domes, away from the main observatory buildings, since one of the dictates of observatory design that became common worldwide from the 1870s on was the move away from centralizing all activities and instruments in the one

Figure 7: Adelaide Observatory with the transit room, tower and Government Astronomer's residence in the background, and the drum-shaped observatory housing the 8-inch refractor in the foreground (sahistorystub.history.sa.gov.au).

building to dispersing them. As has been noted elsewhere (Orchiston, 2017: 239),

> This was especially so of those institutions boasting large refractors [or other telescopes], and an 'astronomical precinct' rather than a single building became the norm (see Donnelly, 1973).

Adelaide Observatory was an example of this, as illustrated in Figure 7. British colonial astronomy therefore offered various Australian observatories that Siam could mimic if it wished to establish a major national astronomical observatory during the nineteenth century.

3 KINGS RAMA IV AND V AND THE NATURE OF NINETEENTH CENTURY ASTRONOMY IN SIAM

3.1 Introduction

King Rama IV (Figure 8), the fourth King of the Chakri Dynasty (Moffat, 1961; Saibejra, 2006), was born on 18 October 1804, and before he became King was known as Prince Mongkut. When he was 14 years old, he became a Buddhist novice for 7 months, according to Royal tradition, and in 1824 he became a Buddhist monk. Just 15 days later his father, King Rama II, passed away and one of Prince Monkut's step-brothers, who was the son of a concubine but was older and more experienced

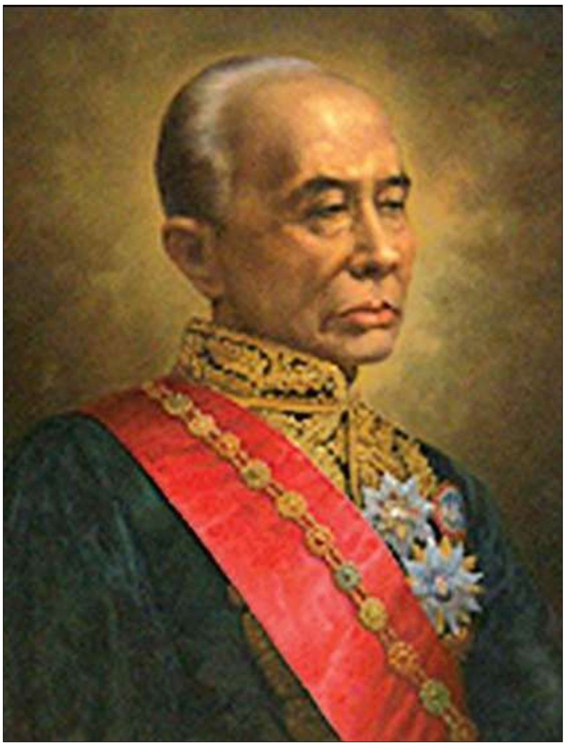


Figure 8: A painting of King Rama IV (https://www.google.com/search?q=king+rama+iv&client=firefox-b-d&sxsrf=ALeKk02Fcwey7PsR909TNbId0olPLsMpHg:1588986995393&source=lnms&tbm=isch&sa=X&ved=2ahUKEwjj06brzaXpAhUXU30KHYFdAQ8Q_AUoAXoECBoQAw&biw=1177&bih=650#imgrc=1DzFBbH8KdeIEM).

in affairs of state, was appointed as Rama III. Prince Mongkut therefore decided to remain in the monkhood, and he was a Buddhist monk and scholar for the next 27 years.

Soonthornthum and Orchiston (2021: 255) note that

> During his 27 years as a monk Prince Mongkut took time to benefit from studying various subjects, both religious and worldly—and especially science and mathematics. He established a new branch of Buddhism, Dhammayut, which had a stricter practice. He made pilgrimages to several cities in Northern Thailand, including Pitsanulok, Sawankhalok and Sukhothai, where he had the opportunity to learn about the lives of his people before he became King. He also discovered many valuable historical documents, and visited archeological sites in Siam.

Prince Mongkut also began learning about Western astronomy (plus chemistry, geography, French and Latin) from the French-born Catholic priest Bishop Jean-Baptiste Pallegoix (1805–1862), who was surprised that

> … the Siamese have several astronomical texts translated from Pali language about the motions of the sun, moon and planets around the zodiac for astrological purposes. But, these knowledges have been distributed only among some Brahmins who are appointed as the 'Royal Astrologers'. They have never used any telescope or astronomical instrument for observations, but rather based on some unclear criteria in their calculations using the old Siam astronomical texts. (Pallegoix, 1977: 319).

Meanwhile, while they were living in Bangkok the American medical missionaries Dr Dan Beach Bradley (1804–1873; Lord, 1969), Reverend Dr Jesse Caswell (1809–1848; Bradley, 1966) and Dr Samuel Reynolds House (1817–1899) also contributed greatly to the Prince's education in science and mathematics, and his familiarity with Western culture, and Drs Bradley and Caswell taught the Prince how to read and write English.

The Prince also became familiar with recent developments in world history and especially about the colonial aspirations of the British and the French in Asia. He noted how the opium war of 1838–1842 between Britain and China led to the ceding of some Chinese territory to Britain, and he realized that Siam had to modernize and to forge its own path in diplomacy, science, and technology if it wished to remain independent.

Prince Mongkut was already interested in Western astronomy before his step-brother died in 1851 and he became Siam's next King, Rama IV. Apart from attending formal classes he also believed in self-education, which he achieved mainly through reading. Thus, apart from traditional Siamese astronomical and astrological texts—which were based on the Indian *Surya Siddhanta*—and Mon astronomical Saros texts, he purchased and read many English-language astronomy textbooks, including Sir John Herschel's (1859) *Outlines of Astronomy* and Lardner's *Handbook of Astronomy* (1853–1856) (see Soonthornthum and Orchiston, 2021). Both of these were major astronomical texts that not only provided information on Western astronomy but also discussed astronomical instruments and observatories, and we know that during the 1850s and 1860s he also carried out telescopic observations of eclipses, comets and a transit of Mercury (*ibid.*).

It is safe to assume from the astronomy books in his library and discussions with Drs Bradley, Caswell and House, and Western dignitaries visiting Bangkok, that King Rama IV would have been familiar with the basic parameters of professional Western astronomical observatories. Yet there is no indication that he decided to establish a Western-style National Observatory anywhere in Siam.

Both King Rama IV and his son, Prince Chulalongkorn, indulged their passion for astronomy by observing the 18 August 1868 total solar eclipse from a swampy mosquito-infested site at Wah-Koa south of Bangkok, where they caught malaria. Sadly, King Rama IV died, but his son survived and on 1 October 1868 became King Rama V (Figure 9). Born in 1853, King Rama V was an enlightened Emperor who continued his father's strategy of modernizing Siam. He made two lengthy trips to Europe and became familiar with Western culture and principles of law and government (which he systematically introduced in Siam). He also had to contend with the colonial ambitions of Britain and France throughout his reign, and almost until his death on 23 October 1910.

Although not an observational astronomer like his father, King Rama V had a knowledge of and interest in astronomy, and would have been familiar with the concept of a National Observatory. But he also decided not to set one up in Siam, and to our knowledge, no Siamese citizens or foreign scientists ever were employed as professional astronomers during his reign or that of his father. Instead, the primary functions that would have been a feature of such an Observatory—had it existed —were all fostered by Kings Rama IV and V through different Government instrumentalities. Let us now examine these functions individually.

3.2 Indigenous Time-Keeping, the Royal Clock Tower, and the World's First National Time Service

King Rama IV provided a time service for the public that was based on traditional Siamese time-keeping rather than Western principles. Thus, a gnomon and the Sun's shadow were used to determine midday, a 'coconut shell water clock' measured each hour of the day, and visual observations pin-pointed sunrise and sunset. For convenience, each 24 hours was divided into two: 'day' (from midnight to midday) and 'night' (from midday to midnight). The King appointed two Time-keeping Officers. One, termed Pun Thiwathit, beat a gong at sunrise, while the other officer, Pun Pinith Chandra, beat a drum at sunset (Krukthong, 2019; Soonthornthum and Orchiston, 2021).

In order to show the time continuously between sunrise and sunset, in 1868 King Rama IV erected an attractive-looking 5-storey clock tower at the Royal Palace in Bangkok, with large clock faces visible from all four cardinal directions (see Figure 10). The clocks showed 'Bangkok Standard Time', and used the Royal Observatory at Greenwich in England as the 'Zero Meridian', with the longitude of the Grand Palace thought to be 100° E of Greenwich. The Royal Clock Tower served as the prime meridian for Siam, and was 6.7 hours ahead of Greenwich (Soonthornthum and Orchiston, 2021).

To maintain the operation of the Royal Clock Tower, King Rama IV set up a Clock Department, headed by the official 'Clock Keeper', and he imported astronomical clocks from the West, like the one shown in Figure 11. He also sent technicians from the Clock Department overseas so that they could learn how to maintain and repair clocks (Krukthong, 2019).

In reality, the Royal Clock Tower and sunrise gong and sunset drum were of little relevance to most of Bangkok's population, who lived beyond sight and ear-shot on the Royal Palace and had little reason or opportunity to visit this prestigious region of the city. So, this local time service was irrelevant to them, and it certainly was inaccessible to those living in other cities, and in towns and villages throughout Siam. For the vast majority of Siamese, time was determined using traditional methods, a gnomon and the solar shadow for midday and a coconut shell with a small hole in the bottom that was placed in a water container and took exactly one hour to fill with water

Figure 9: King Rama V (after *The Story of Rama V*. n.d.).

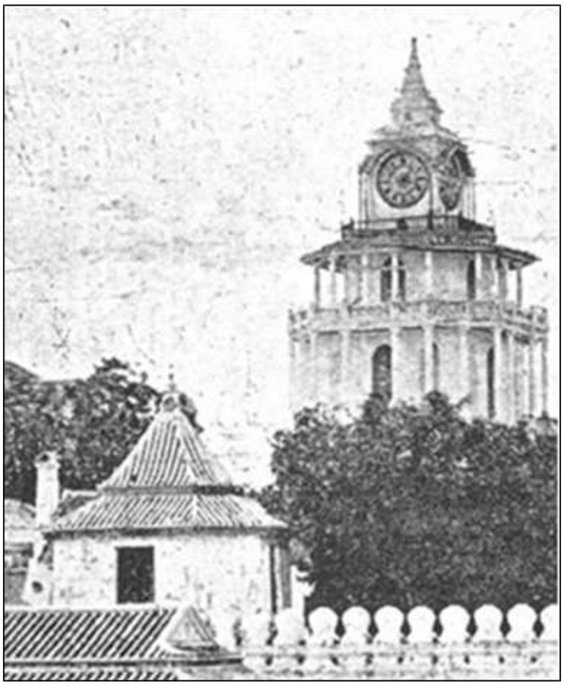


Figure 10: A close-up of the visually-appealing 5-storey Royal Clock Tower erected by King Rama IV, cropped from an 1879 photograph of the Royal Palace (1879-outside-grand-palace-sanam-lunah-grounds).

and sink. In addition, people in the countryside noted local 'natural clocks', such as the innate behavior of the buffalo, where 'buffalo afternoon' and 'buffalo into the stall' had special temporal meaning. Meanwhile, from 1887,

Figure 11: Example of an astronomical master clock (after Thai Navy …, n.d.).

those living in and near central Bangkok also could enjoy the sound of a 'time gun'—a cannon that the Royal Siam Navy fired daily at noon. This was King Rama V's sole major time-keeping initiative.

King Rama IV realized that if he was to successfully host Western astronomers intent on observing the 1868 total solar eclipse from Wah-koa, about 240 km SSW of Bangkok, then he needed to supply them with a reliable time service that met international standards. Thus, in 1868 he initiated a standardized national time service, and as Soonthornthum and Orchiston (2021: 270) have proudly pointed out,

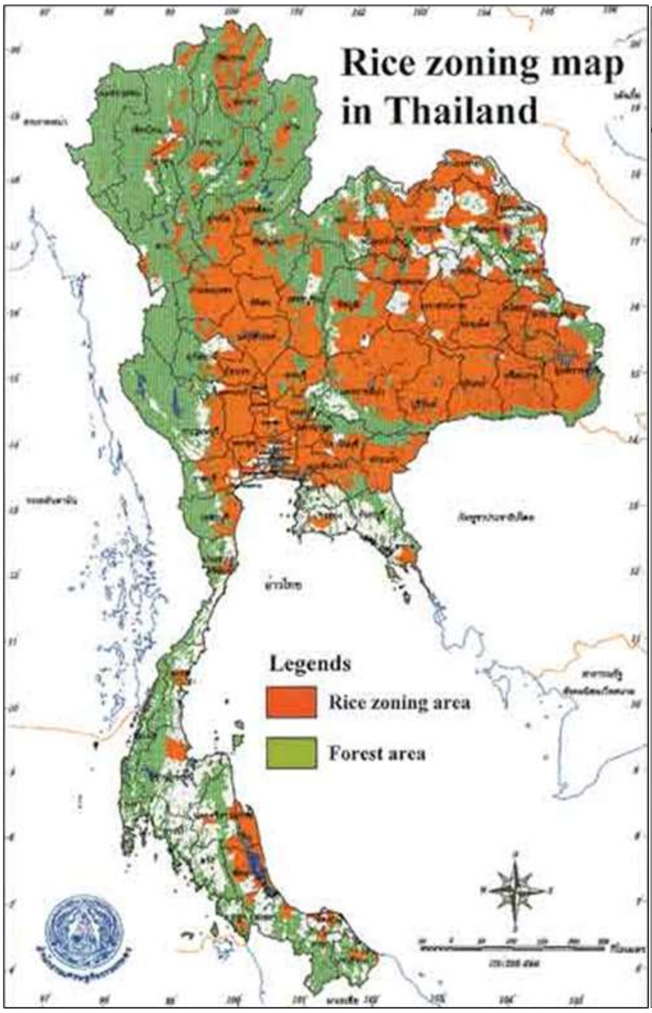
> … Siam was the first country in the world to [do this] … followed soon after, on 2 November 1868, by New Zealand (King, 1902). Siam and New Zealand were the pioneers, long before other countries around the world introduced national time services.

King Rama IV also wished to use astronomy for non-scientific purposes, and the Royal Clock Tower was a case in point as it created a 'modern image' in the eyes of Westerners and was "… an expression of civilization … It showed the West that Siam was prosperous just like a Western nation …" (Krukthong, 2019). Not only this, but in building an aesthetically-appealing tall clock tower the King showed that his nation could quickly adapt to the need to modernize Siamese society and was open to adopting knowledge derived from the West. So, from this perspective the Royal Clock Tower was a political and promotional masterpiece. Meanwhile, there was no need to affiliate the Royal Clock Tower with a new National Observatory—it functioned perfectly under the auspices of the Clock Department—while the bulk of the Siamese population continued to rely on tried and true traditional methods of time-keeping. Therefore, a National Observatory would be redundant!

3.3 Monsoons, Flooding, Rice Cultivation and Meteorology

During the nineteenth century Siam was predominantly a rural nation, and rice-growing was the lifeblood of the population, although in certain regions the cultivation of cotton, fruit trees, tobacco and vegetables was important. An important factor, also, was the emergence of rice as an export commodity:

> Exports seem to have been dependant [*sic*] on assured domestic supply of rice up to about 1850 when rice represented less than three percent of the Kingdom's exports. This rose to 41 percent by 1867 and 78 percent by 1888 (Owen, 1971) with concomitant increases in farm sizes for those oriented to export production. (Falvey, 2001: 287).



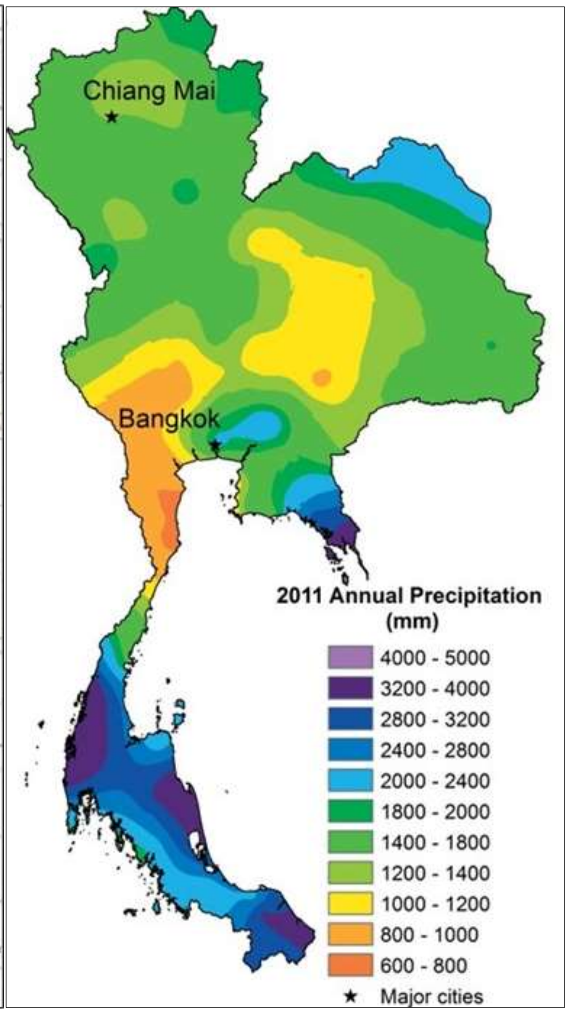


Figure 12 (left): A map of Thailand showing the geographical distribution of forest areas in green and major rice-growing regions in orange (after Karnchanasutham, 2010).

Figure 13 (right): A map showing annual rainfall in Thailand; some of the extensive rice-growing region around Bangkok received substantially heavier annual rainfall than other rice-growing regions (adapted from https://rmets.onlinelibrary.wiley.com/cms/asset/2a5f2a5c-bb26-49e0-975b-256bb2e57de3/wea2133-fig-0002-m.jpg

Successful harvests at worse allowed farmers to survive and at best afforded them prosperity (e.g., see Grabowsky, 2017: 227, n.145, 230–231; Hallett, 1890: 231–253), so knowledge of the seasonal NE and SW monsoons was paramount. As Buckley et al. (2007: [1]) stress, changes in monsoonal rainfall "... may alter the strength, timing or distribution of the monsoon [and] can result in drought or floods, crop failure and famine …". Monsoons, more than any other factor, controlled the purse-strings of farmers and their families year after year.

Fortunately, all of the major rice-growing regions of Siam were inland, out of the reach of most cyclones (see Figure 12), so there was no priority to religiously monitor cyclones, as occurred in the Philippines and Indochina (present-day Vietnam). That said, intense cyclones that made landfall along the coast of Vietnam could evolve into tropical rain depressions and dump abundant rain on Thailand as they moved westwards. However, other than when they were occasionally exposed to these tropical depressions, most of Siam's principal rice-growing regions enjoyed moderate to light rainfall (Figure 13) and flooding was not an issue, except for the large low-lying flood-prone region that surrounded Bangkok and extended far to the north of the capital (Figure 14). Had King Rama IV chosen to establish a National Observatory that included a commitment to meteorology, this would certainly have assisted farmers in this region, and information about imminent heavy rainfall would definitely have been helpful to politicians and citizens living in the capital, allowing them to anticipate imminent flooding and plan remedial action—something that Bangkok and its environs desperately needed given the enor-

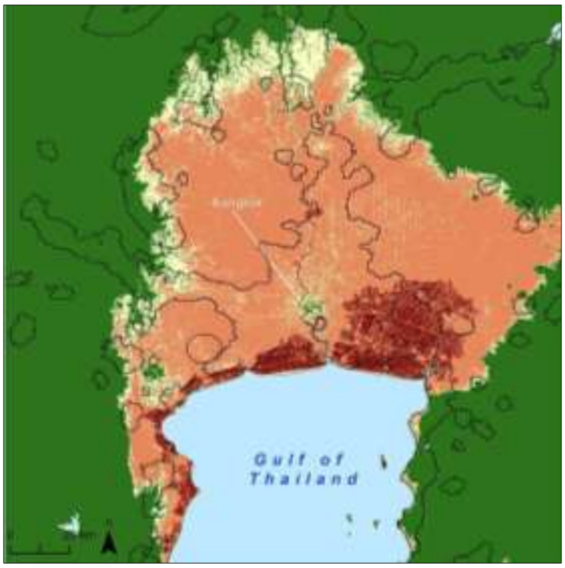


Figure 14: The elevation of land in the vicinity of Bangkok. Key: 0–3m red; 4–7m pink; 8–10m white; >10m green (wiki-wand.com/en/Bangkok).

mous watershed catchment of the Menam River and its major tributaries (see Figure 12).

Despite a clear need, meteorology—as a scientific discipline—was only introduced to Siam in 1905 when Admiral Kromluang Chumporn Khate Udomsakdi, the Commander-in-Chief of the Royal Siam Navy, decided to include it in the navigation course. Seven years later a textbook on this subject was published, written in Thai by a Lieutenant in the Royal Siam Navy (TMD …, n.d.).

However, Siam's first national meteorological service, the Meteorological and Statistics Section, within the Water Management Division

Figure 15: Henry Alabaster was Siam's first professional surveyor (https://www.ayutthaya-history.com/Temples_Ruins_Phanan Choeng_Alabaster.html).

of the Royal Irrigation Department (under the Ministry of Lands and Agriculture) was only established in 1923. Consequently, observing stations were set up in various provinces, and data collected on temperature, rainfall and floods were used to plan weirs and reservoirs for flood control and the construction of agricultural irrigation systems throughout the nation (TMD …, n.d.; Thai Meteorological Department, n.d.).

A major change occurred in August 1936 when the Meteorological and Statistics Section was transferred to the Hydrographic Department of the Royal Siam Navy. There it was known as the Meteorological Division, and in June 1942 it finally was upgraded to a standalone Department (Thai Meteorological Department, n.d.). So, in Siam (and in Thailand, from 1939), meteorology never was associated with astronomers or with an astronomical observatory.

3.4 Cadastral Mapping, International Intervention and Changing Borders: The Need for a Survey Department

Another common element of some British colonial observatory operations, initially at least, was a trigonometrical survey, so what need was there for geodetic and cadastral mapping in Siam, and how did King Rama IV and V address these in the absence of a National Observatory?

Giblin (1908) has provided a useful outline of how and why the Siam Survey Department was founded. Around 1875 improvements were occurring in Bangkok and the need arose for survey work to be carried out. King Rama V selected some officers from the Royal Guard, and

> These … were formed into a special company called 'Military engineers of the royal Bodyguard.' Their commandant was the late Mr. Alabaster, his Majesty's adviser …" (Giblin, 1908: 121).

Henry Alabaster (1836–1884; Figure 15) was born in England and educated at King's College, London, before sailing for Bangkok in 1856 to serve as an interpreter in the British Consular Office and then as Acting Consul. In 1873 he accepted the post of private secretary and adviser to King Rama V, and

> … oversaw many modernization efforts at this time, many of Thailand's firsts. This included the building of roads … bridges, libraries, and museums, the use of modern cartographical techniques, and sending students

> abroad for study … One of his roles was Director of the Royal Museum and Garden … [and] He was the first director of the kingdom's map-making division, established in 1875, and had teams of surveyors develop maps for use in building roads and telegraphs as well as protecting territorial waters … (Henry Alabaster, n.d.).

Alabaster was involved in the 1868 and 1875 solar eclipse expeditions that are discussed below in Section 4. He was well-known in Bangkok, and highly-regarded, and his premature death in 1884 at the age of 48 was a shock for all. Assisting Alabaster was fellow Briton, Captain Alfred John Loftus, FRGS (1836–1899), who had lived in Siam since 1871. According to his biographer, Loftus' official position

> … consisted of surveying the coasts and rivers, telegraph and railway routes and the superintending of observatory building for noting eclipses …
>
> As an author of geographical and topographical works Captain Loftus was an accredited authority and his works have done much towards revealing the richness of the products of his adopted country. He published several maps of Siam and its dependencies … (Anonymous, 1899: 2).

In 1880 Captain J. Hill and the Irishman James F. McCarthy (1853–1919) from the Survey of India came to Siam to link the Indian and Burmese surveys with Alabaster's survey near Bangkok. Once the survey was completed King Rama V employed McCarthy as Government Surveyor (Giblin, 1908). Soon after, in 1882, Prince Damrong Rajanubhab (1862–1943), one of King Rama V's uncles and the commander of the Royal Guard Regiment, came up with the idea of forming a Siam Survey Department. But trained surveyors were required first, so in 1882 McCarthy established a Survey School and "Thirty men were selected from the royal bodyguard for training." (Giblin, 1908: 122).

In September 1885 the surveyors were separated from the Royal Guard Regiment, and became the Royal Survey Department (Royal Thai Survey Department, n.d.), with McCarthy as the Director. Then in December 1894 the Australian, Ronald Worthy Giblin (1863–1936; Pearce, 1981), joined the Survey Department, and he became its second Director in 1901 after McCarthy retired (Giblin, 1908). Giblin had an interest in the history of astronomy in Siam, and published papers on this topic (e.g. see Giblin, 1904; 1909). Under Giblin's guidance the Survey Department and the Survey School developed rapidly, and for a few years the School even had branches in three provinces (Giblin, 1908).

Like his father, Rama V was concerned about the colonial threats posed by Britain and France, and one of Alabaster's recommendations was to begin the accurate mapping of Siam's borders, and its coastline—especially around the Gulf of Siam. Without doubt, this was one of the most important tasks of the Siam Survey Department during the late nineteenth and early twentieth centuries, when

> The idea of overlapping frontier zones, based on the primacy of manpower, was replaced by the European concept of a territorial state with clearly defined border lines." (Grabowsky, 2017: 237).

This primarily occurred because of the Franco-Siamese War of 1893 (see Tuck, 1995) and the Anglo-Siamese Treaty of 1909, with Siam giving up territory to Britain in the north and south, and to France in the east. However, even before this occurred, Survey Department staff were busy surveying in the far south and far north of Siam during 1883–1886. We should not forget that each year monsoonal rains limited the number of days when successful survey work could be carried out.

While establishing Siam's international borders was the Survey Department's primary concern, it also had other tasks to address. For example, from 1896 the Department was engaged in cadastral surveys, which involved establishing the boundaries of small land parcels in order to assign ownership, allow land registration and print land title deeds (Royal Thai Survey Department, n.d.). Previously

> Small-holders had enjoyed the right to use land without the ability to mortgage or sell it. With the introduction of a Department of Survey in 1883, the first issuance of titles in 1890, and the first land auction in 1912 by the Ministry of Finance … policies associated with the wave of modernisation aimed to create a powerful Monarchy supported by taxed independent small-holders. (Falvey, 2001: 289).

For further details about the Siam Survey Department and the mapping of Siam see Giblin (1908), McCarthy (1900) and Winichakul (1997), and for information on Siam's much earlier indigenous map-making achievements see Wade (n.d.).

3.5 Reflecting on Colonial Role Models: Other Possible Functions of a National Observatory

There were two other functions that sometimes preoccupied British colonial observatories and we should briefly discuss these in a Siamese context. They were geomagnetism and seismology.

As we saw in Section 2, nineteenth century initiatives in geomagnetism were largely undertaken as part of Edward Sabine's 'geomagnetic crusade', and notwithstanding basically amiable diplomatic relations with Britain, Siam was never part of this ambitious international endeavor. Had King Rama IV or King Rama V displayed a personal research interest in geomagnetism, circumstances may have been very different.

The same was true of seismology. Unlike Japan, Indonesia and New Zealand, Thailand is not located on the infamous 'Ring of Fire' so is not known for major earthquakes. Nonetheless, there are fault zones in northern, western and southern regions of the nation (Figure 16), but only the northern zone has been associated with (mainly small) earthquakes (Pailoplee and Charusiri, 2016: Figure 1; but see Ornthammarth, 2019). Because of the distance of far northern Thailand from Bangkok, any earthquakes that were detected in the nineteenth century seem not to have attracted the attention of King Rama IV or his son, and they made no attempt to form a Government department or section to investigate these events. Indeed, the first recording of an earthquake made in Siam using a seismograph only occurred in 1912, two years after the demise of King Rama V (Ornthammarth et al., 2010).

4 SIAM AND SOLAR ECLIPSES: CATALYSTS FOR THE DEVELOPMENT OF PROFESSIONAL ASTRONOMY IN SIAM/THAILAND

In this section we will discuss the three European solar eclipse expeditions that were instrumental in launching professional astronomy in Siam in the twentieth century.

4.1 The French and the 1868 Eclipse

On 18 August 1868 a total solar eclipse would be visible from Wah-koa on the west coast of the Gulf of Thailand south of Bangkok (see Figure 17). Like his predecessor King Narai, Siam's King Rama IV had a passion for Western astronomy and for eclipses, so he invited a team of three French professional astronomers to visit Siam and observe the eclipse.

The King also offered to provide suitable accommodation for the visiting astronomers and their scientific instruments, which comprised 40-cm and 20-cm reflecting telescopes with silver-on-glass primary mirrors, a 15-cm refractor, a meridian telescope and an astronomical clock.

When the French arrived at their observing camp at Wah-koa they found wooden huts (not observatories) erected for their instruments, and the refractor, meridian telescope and astronomical clock were housed in two of these, while the two equatorially-mounted reflecting telescopes were erected outdoors, in the open, with temporary shelters available to shield them from the elements, if necessary—see Figure 18. We are not informed if the rooves of the huts housing the refractor and meridian telescope were modified to facilitate astronomical observations, but we can presume that this must have happened given that the French successfully made night-time transit observations with the meridian telescope in order to maintain a local time service.

Marseilles Observatory Director Édouard Stephan (1837–1923), the leader of the expedition, reported that the French visual and spectroscopic observations of this eclipse were a success, and useful new data on the nature of the prominences were accumulated. For details of the French expedition to Siam in 1868 and their observations of the 18 August total solar eclipse see Orchiston and Orchiston (2017).

When viewed in an historical context, this eclipse can be identified as a 'watershed event' in nineteenth century solar physics. As well as in Siam, it was successfully observed from Aden, various sites in India, near the coast of Borneo, and in the Celebes in the Dutch East Indies. With maximum totality of 6 minutes 47 seconds, it was one of the longest-lasting total solar eclipses on record, and observations—especially those from India—helped determine the chemical composition of the prominences, the chromosphere and the corona. As well, observations during this eclipse led directly to the discovery of a new element, helium (Nath, 2013; Nath and Orchiston, 2021).

Before moving to the next solar eclipse there is one important aspect of the 1868 event that deserves special attention: as well as recognizing its scientific significance, King Rama IV realized that he could use this eclipse as a political weapon to try and help neutralize British and French colonial designs on Siam. This interesting case of international astro-politics is discussed by Aubin (2010) and Orchiston and Orchiston (2021).

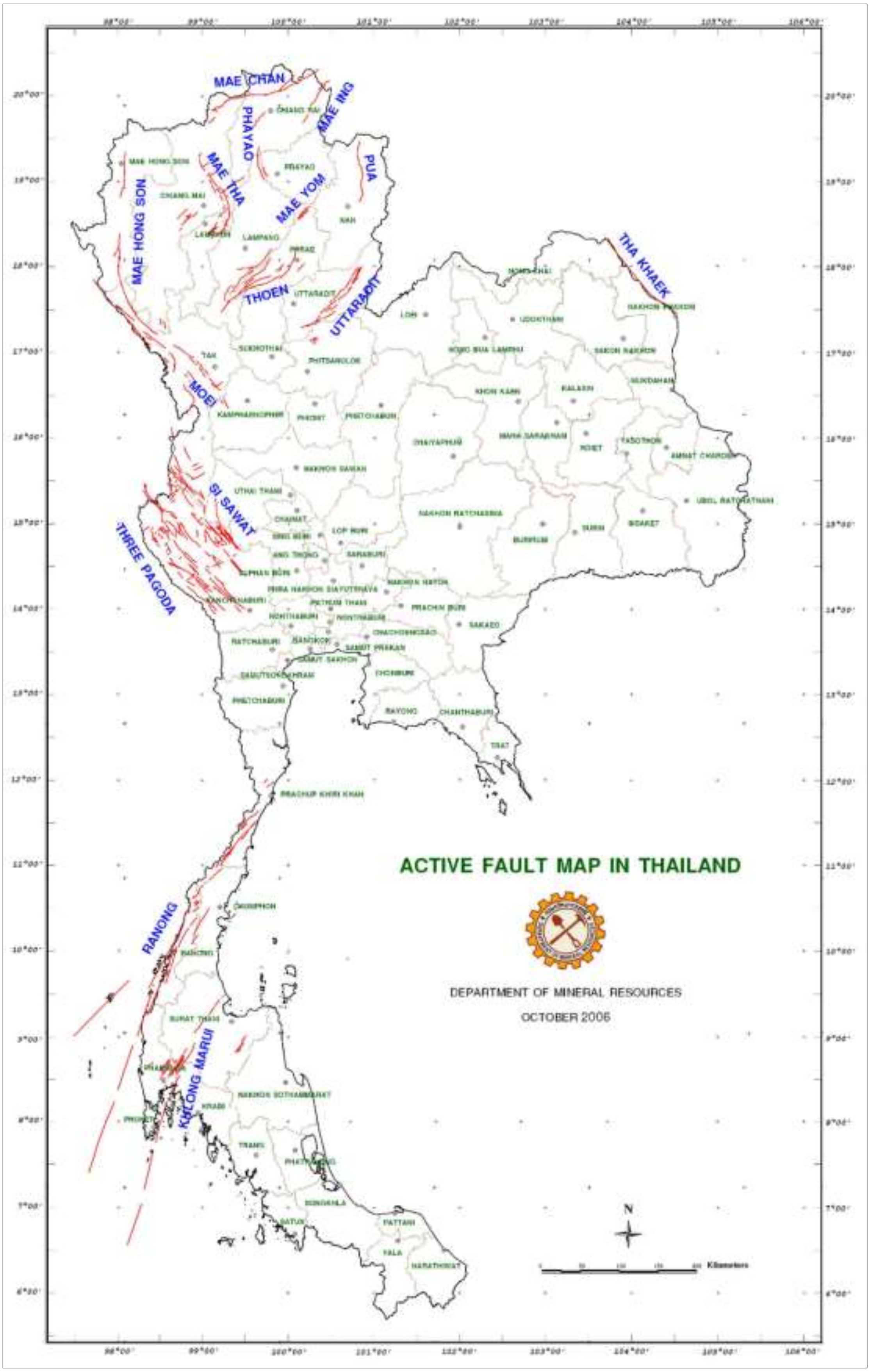


Figure 16: A map showing the active faults of Thailand (in red); only those in the northern zone are associated with regular (generally small-scale) seismic activity (after Kosuwan, Takashima and Charusiri, n.d.).

Figure 17: A map showing the center-line (in red) of the path of totality of the solar eclipse of 18 August 1868; the red bull's eye marks Wah-koa (after Espenak and Meeus, 2006; map modification: Wayne Orchiston).

4.2 British and French Observations of the 1875 Eclipse

King Rama IV paid the ultimate price for his commitment to astronomy: he contracted malaria during the 1868 eclipse and sadly he subsequently died. His son also caught malaria but survived, and in 1875 he was able to continue his father's astronomical interests by inviting British and French astronomers to Siam to observe the 6 April 1875 total solar eclipse. Totality passed across the Nicobar Islands (in the Indian Ocean), Siam, Cambodia and Vietnam (Figure 19).

Head of the British expedition was a youthful Manchester University astronomer, Arthur Schuster (1851–1934), while the famous Pierre Jules César Janssen (1824–1907) represented France. Janssen and his wife just happened to be on their way home from observing the 8/9 December 1874 transit of Venus from Japan so they did not have any astronomical instruments of their own and relied on Schuster to provide them with observations (Launay, 2012: 83).

The British set up their eclipse camp at Chulai Point, which also was on the west coast of the Gulf of Thailand, about 135 km north of the 1868 eclipse site. On this occasion, King Rama V also provided accommodation and makeshift facilities for the scientific instruments. The latter comprised an equatorially-mounted refracting telescope and a horizontal photoheliograph, fed by a siderostat. When not in use, the siderostat and its drive (Figure 20) were covered by a small removable 'house' adjacent to a larger makeshift structure that sheltered the collimator lens and photographic plate-holder (Figure 21). The refractor,

Figure 18: A photograph by Rayet of the French eclipse camp, showing instrument huts and the 40-cm (left) and 20-cm (right) reflecting telescopes set up outdoors (courtesy: Archives, Observatoire de Marseille, 132 J 84).

meanwhile, was mounted on the verandah of the 'Principal Observatory' (Figure 22), in a position that would allow direct observation of the Sun during the late-morning eclipse. Visanu Euarchukiati (2021b) has intensively researched this expedition, and identified the location of the British eclipse camp.

Like his father, King Rama V was interested in using the solar eclipse for more than just research, and in order to promote the study of solar astronomy among the Royal Family he arranged an eclipse drawing competition at the Grand Palace back in the Siamese capital, Bangkok, where the eclipse also was seen as total (for details see Euarchukiati, 2021a).

Note that as with the 1868 French eclipse camp, none of the buildings erected by the Siamese hosts in 1875 mirrored the stereotyped domed astronomical observatory buildings seen at nineteenth century Western professional observatories, although the 1875 photoheliograph was housed appropriately and was somewhat reminiscent of the horizontal telescopes used by the Americans during the 1874 transit of Venus (e.g. see Orchiston, 2016: Figures 15.3 and 15.4).

4.3 The British and Germans and the 1929 Eclipse

Siam's third flirtation with Western total solar eclipse expeditions occurred in 1929, when the 9 May eclipse would be visible from Malaya, Siam, Vietnam and the Philippines. With totality lasting about 5 minutes this eclipse offered an exciting opportunity to confirm Einstein's General Theory of Relativity. Consequently, King Rama VII invited British and German eclipse parties to Siam, and they were located 24 km apart in and near the town of Pattani in far southern Siam (Soonthornthum et al., 2021). In order to allow for unpredictable weather, a companion British camp was set up just across the border at Alor Star, in the Unfederated Malay State of Kedah (Noor and Orchiston, 2021). These neighboring observing sites are shown in Figure 23.

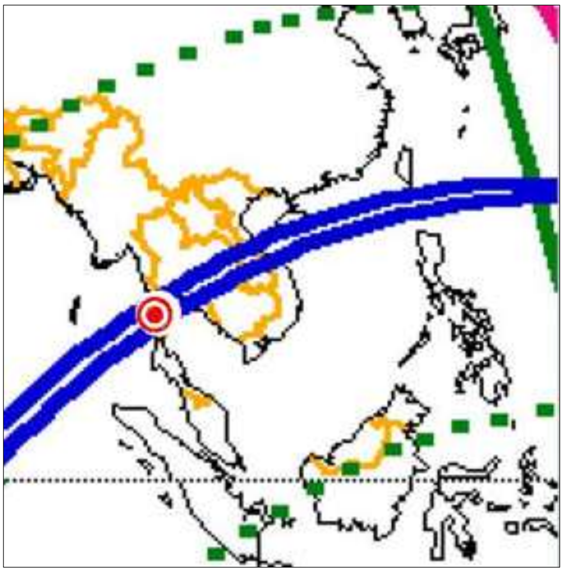


Figure 19: A map showing the path of totality of the 6 April 1875 total solar eclipse; the red bull's eye marks the British eclipse camp just south of Chulai Point (after Espenak and Meeus 2006; map modification: Wayne Orchiston).

Given the importance of the Einstein experiment, photography was the obvious research approach, and both Pattani foreign expeditions came with astrographs (e.g. see Figure 24) and prefabricated observatories. The 'clam-shell observatory' used by the Germans is shown in Figure 25. Unfortunately, cloudy weather prevailed on the vital day and the eclipse was not clearly visible from Pattani (or Alor Star), although the Germans were able

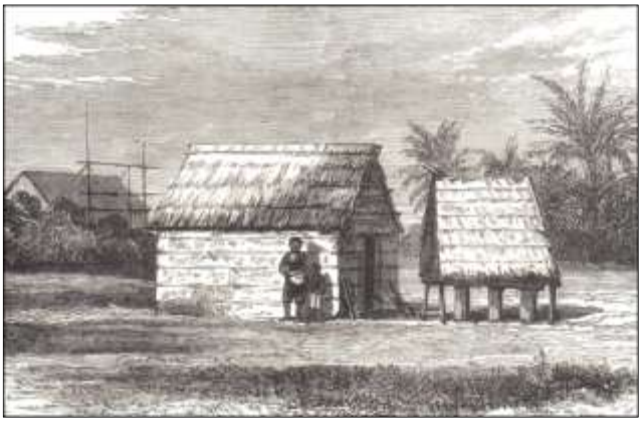


Figure 20 (left): A close-up of the siderostat and drive (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

Figure 21 (right): An engraving of the Siderostat Observatory, mistakenly labeled No. 1 observatory (after *Illustrated London News*, 19 June 1875).

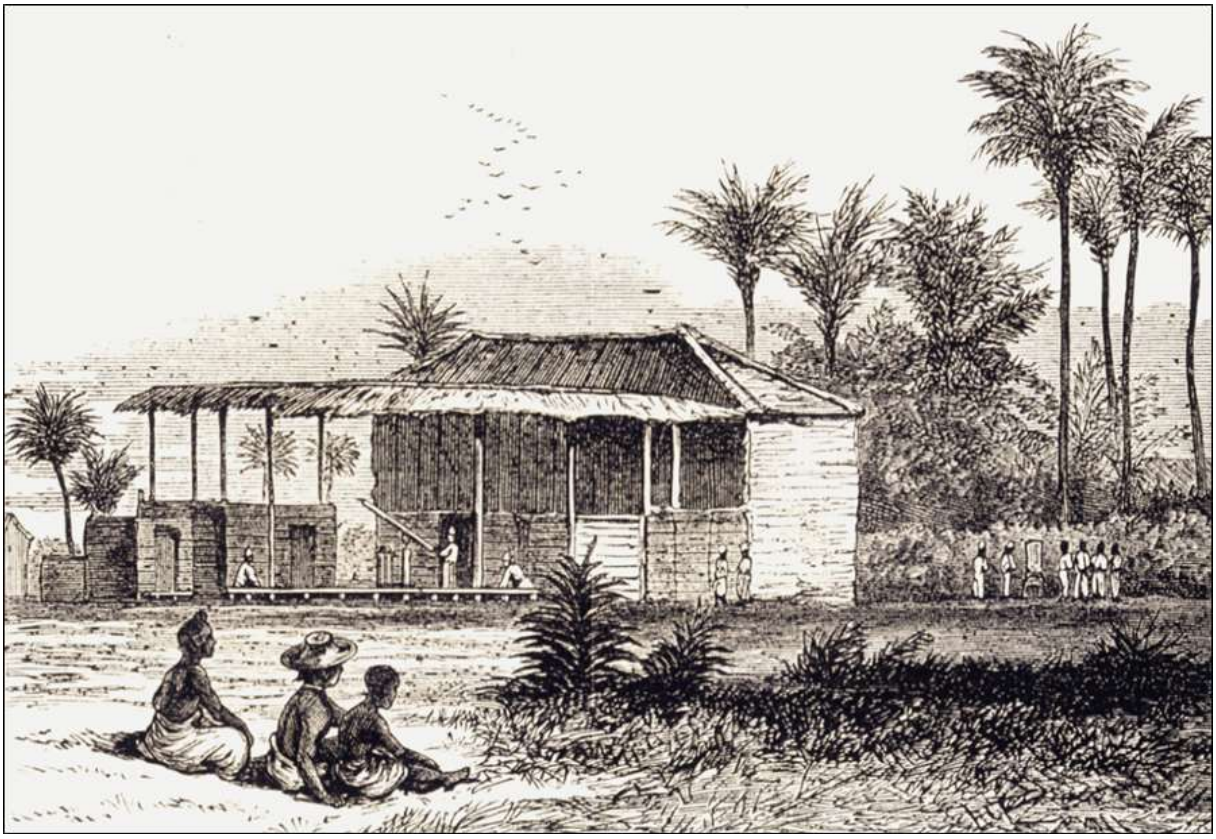


Figure 22: An engraving of the 'Principal Observatory', showing the refracting telescope set up on the verandah (after *Illustrated London News*, 19 June 1875).

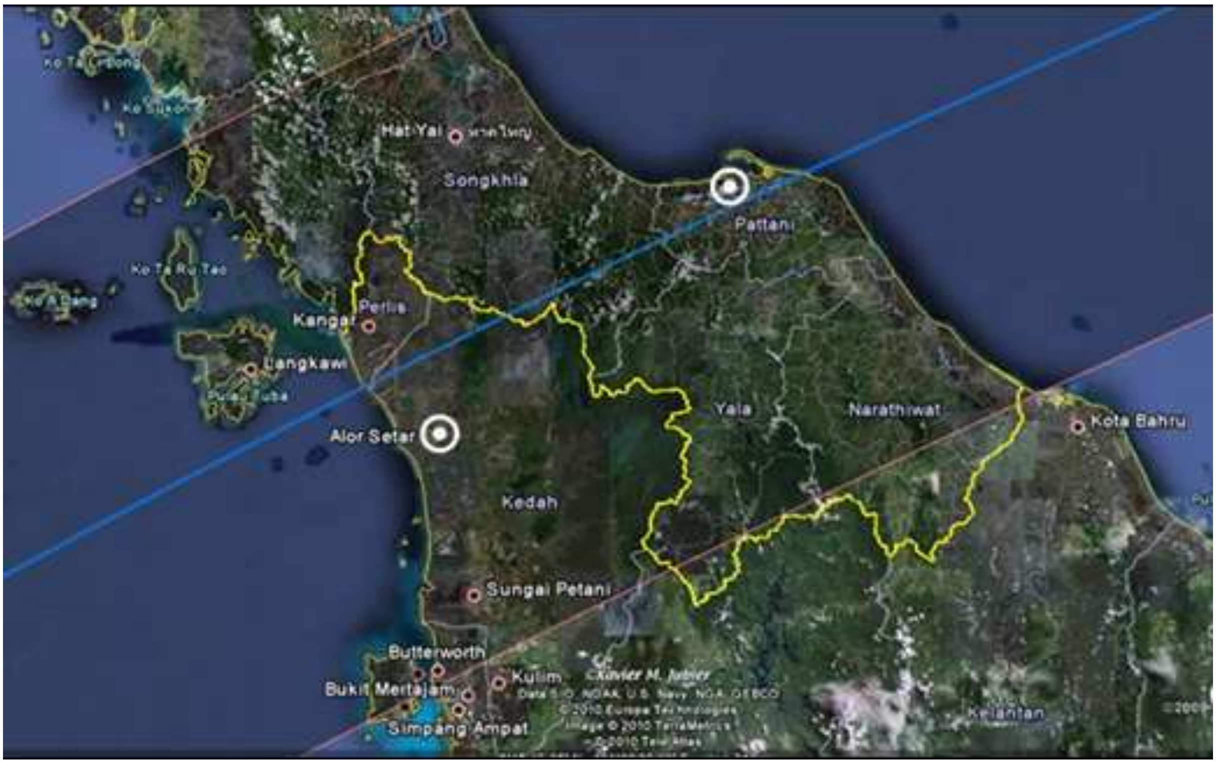


Figure 23: A map showing the path of totality (between the two pink lines), in the vicinity of the Kedah–Siam border (the yellow line). The eclipse center-line (blue) passed close to Alor Star in Kedah and Pattani in Siam, where the two components of the British expedition were based (shown by white bull's eyes). Map scale: the distance between the eclipse camps in a straight line is about 140 km (base map: Google; map modifications: Azam Noor and Wayne Orchiston).

Figure 24: The German astrograph being demonstrated to a Siamese officer (photograph: King Prajadhipok Museum).

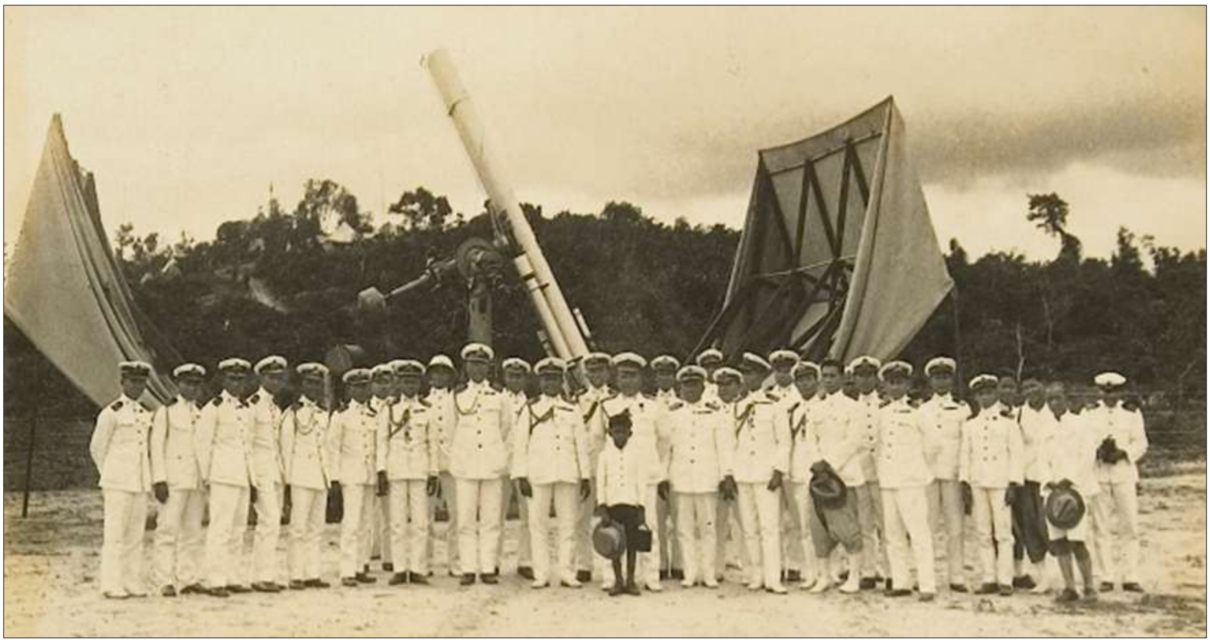


Figure 25: A group of Royal Siam Navy officials at the German observing camp, showing the open observatory and the astrograph ready for use (photograph: King Prajadhipok Museum).

Figure 26: Colonel Phra Salvidhan Nides, Siam's first university lecturer in astronomy (courtesy: Office of the National Research Council of Thailand).

to take a number of photographs. Details of the Pattani initiatives are outlined by Soonthornthum et al. (2021).

5 THE DEVELOPMENT OF PROFESSIONAL ASTRONOMY IN SIAM AND THAILAND DURING THE TWENTIETH CENTURY

5.1 The Teaching of Astronomy in the Universities and the First Astronomical Observatories

Even though Siamese observations of the 1929 eclipse made almost no contribution to solar physics, this event made a huge local impact and was the catalyst that led to the emergence of academic astronomy in Siam. As a result, Colonel Phra Salvidhan Nides (Figure 26), a prominent member of the Siamese committee that organized the construction of the British and German eclipse camps in 1929 and welcomed the European astronomers, ended up teaching astronomy courses at Chulalongkorn University for science and engineering students. This was Siam's first university, and was founded in Bangkok in 1919 and was named after King Rama V (Soonthornthum, 2017: 280–281).

Figure 27: Professor Rawi Bhavilai, Thailand's first solar physicist (after Anonymous, 2008).

Chulalongkorn University's commitment to astronomy continued when Rawi Bhavilai (1925–2017; Figure 27) joined the Physics Department in 1944. Bhavilai would remain at the University until he retired as a Professor in 1986 (Anonymous, 2017a). During his tenure he secured a Colombo Plan Scholarship and studied for an MSc degree at the University of Adelaide (Anonymous, 2008), graduating in 1952. Subsequently, he continued this love affair with Australian academia by studying for a PhD in astronomy at the Australian National University in Canberra, while based at nearby Mount Stromlo Observatory. In 1965 he was awarded the doctorate for a thesis titled "The Structure and Dynamics of the Solar Chromosphere" (Anonymous, 2017b).

Professor Bhavilai then

> … established a solar research group at Chulalongkorn University and not long before the publication of his book *The Fine Structure of the Solar Corona* (Bhavilai, 1971) a 15-cm f/10 Zeiss solar chromospheric telescope was installed at the University. This instrument is described in the book … [which] was one of twenty-one books that Professor Bhavilai wrote or edited, but most were in the fields of literature and Buddhism. (Orchiston et al., 2019: 206–207).

So, although he is well known to astronomers, "His life's work … has seen him explore areas as diverse as philosophy, physics, Buddhism and poetry". (Anonymous, 2008). Professor Bhavilai was truly a 'Renaissance Man'.

Although Professor Bhavilai concentrated on research in solar physics, by 1989 the Physics Department had expanded into astrophysics, and

> In October 1989 a 0.45-m reflecting telescope was donated to Chulalongkorn University by the Government of Japan under a cultural grant aid program for the promotion of astronomical edu-

> cation and research in Thailand. (Soonthornthum, 2017: 281).

However, Chulalongkorn University was not the first Thai university to embrace astrophysics, for this was pioneered in 1977 at Chiang Mai University in northern Thailand, when astronomy became part of the Faculty of Science curriculum (Soonthornthum, 2017). Writing back in 1993, the Head of Astronomy within the Physics Department, Boonrucksar Soonthornthum (1993: 455) explained that at that time Chiang Mai University had the only functioning astronomical observatory in Thailand, which was

> … equipped with a 16 inch (40 cm) Cassegrain reflecting telescope. The observatory was founded in January 1977 and … is about 12 kilometers from the campus on Doi Suthep Mountain with an altitude of 784 meters [2,572 feet] above sea level … [and has] a sliding roof …

This unique Thailand facility was named the Sirindhorn Observatory, after one of King Rama IX's daughters, Princess Sirindhorn, who was (and continues to be) a major supporter of professional astronomy in Thailand. Note that Sirindhorn Observatory featured a roll-off roof instead of the more conventional hemispherical dome.

Initial research projects concentrated on stellar photoelectric photometry, especially of eclipsing binaries, using a 'Starlight-1' photometer and photon counter and Johnson U,B,V filters. However,

> … the old 16-inch telescope has very limited capacity in certain photoelectric observations, especially for faint celestial objects. The results of some faint stars contain significant fluctuations and we realize that a larger telescope and better detectors are needed for more accurate observations. (Soonthornthum, 1993: 457).

The Astronomy group at Chiang Mai University initiated a research collaboration with Yunnan Observatory in the People's Republic of China, where there were 60-cm and 1-m telescopes (Soonthornthum, 1997), and later they provided a CCD spectrograph and a CCD photometer for their 40-cm telescope (Soonthornthum, 2001). In 1996 a 0.5-m telescope replaced the old 40-cm reflector (Kramer, 2007).

These developments at Chiang Mai University led, ultimately, to the final phase in the development of professional astronomy and astrophysics in Thailand, with the establishment in 2009 of the National Astronomical Research Institute of Thailand (NARIT) in Chiang Mai. The founding Director was none other than Associate Professor Boonrucksar Soonthornthum (Figure 28).

5.2 The Founding and Development of the National Astronomical Research Institute of Thailand

As Soonthornthum (2017: 284) has pointed out,

> The development of astronomical research in Thailand took a crucial leap forward when on 20 July 2004 the Government approved the "Establishment of the National Astronomical Research Institute of Thailand (NARIT)" under the Ministry of Science and Technology. On 1 January 2009 NARIT was approved by the Government and officially established with the status of a public organization responsible for policy-making and strategic planning in the development of astronomy in Thailand.

Figure 28: Associate Professor Boonrucksar Soonthornthum, Dean, Faculty of Science, Chiang Mai University, 2000–2005 (https://www.science.cmu.ac.th/english/deanhouse.php).

Elsewhere Soonthornthum (2007: 135) explained that

> The main facility of NARIT is the National Observatory [Figure 29] which is located on the very top of the highest mountain in Thailand at the altitude of 2550 metres above mean sea level. It is named Doi Inthanon, in Chiang Mai province of northern Thailand, which is

Figure 29: The Thai National Observatory (TNO) is located near the summit of Doi Inthanon, a 2-hour drive west-southwest of Chiang Mai (travel.mthai.com).

> also renowned for the superb climate and tourist attractions. Seeing tests and weather monitoring at the site have been carried out since March 2006. The average seeing is 0.7 arc sec …

We believe that the growth of NARIT since 2009 has been phenomenal, and Kramer (2007: 127) refers to this as a 'Golden Era' for Thai astronomy. The NARIT staff has grown to more than 200; there are vibrant schools and public outreach programs; and a Research and Development group carries out wide-ranging astrophysical research involving mainly optical and radio astronomy. There also are research groups studying the Earth's climate and near-Earth asteroids, and the history of astronomy.

The astronomy and astrophysics research staff have access to NARIT telescopes, that range in aperture from 0.5 meters to 2.4 meters. The principal instrument at the Thai National Observatory (TNO) near (but not quite at) the summit of Doi Inthanon[1] is the 2.4-m Ritchey-Chrétien Thai National Telescope (TNT), which is shown in Figure 30. Her Royal Highness Princess Maha Chakri Sirindhorn officially opened the TNO in January 2013, just four years after NARIT was founded.

In order to conduct research collaborations and 24-hour monitoring of target stars, NARIT has also established an international network of 60-cm to 1-m telescopes sited in Australia, Chile, China and the USA (see Figure 31). Most of these are robotic telescopes and can be operated from the NARIT headquarters in Thailand.

Figure 30: Two views of the automated 2.4-m Ritchey-Chrétien Thai National Telescope (TNT). Left: undergoing testing prior to its installation at the TNO; right: installed and operational at the TNO (courtesy: NARIT).

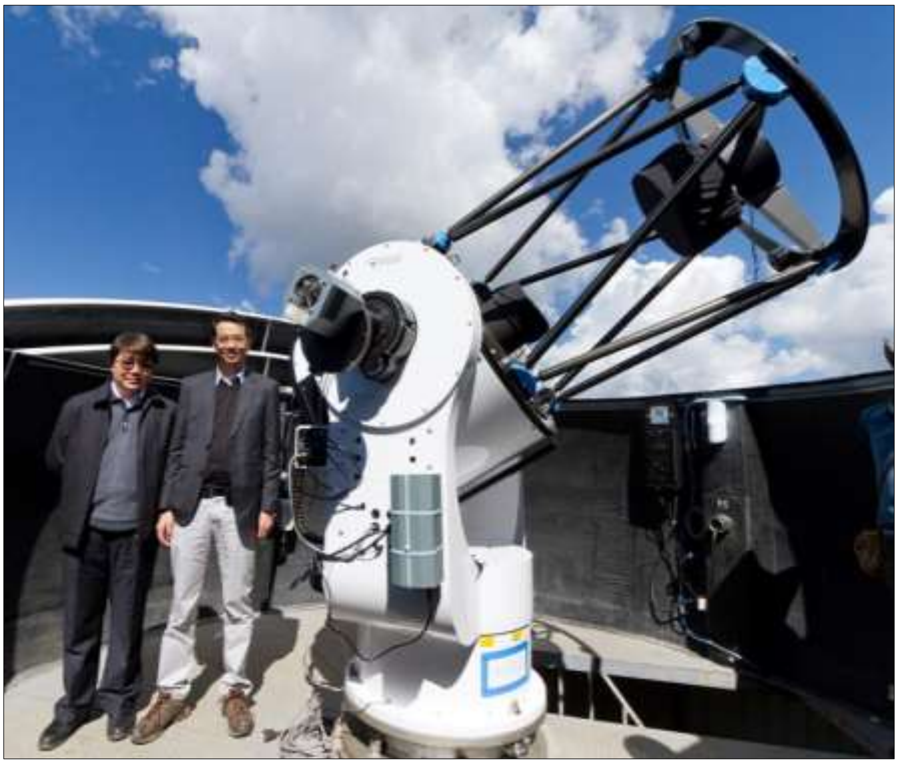


Figure 31: The 0.7-m Thai Robotic Telescope at Gao Mei Gu Observatory in Yuannan Province, People's Republic of China. Second from the left is Dr Saran Pochyachinda, the current Director of NARIT (courtesy: NARIT).

Figure 32: The 40-m Thai National Radio Telescope, sited between Chiang Mai and Chiang Rai (courtesy: NARIT).

Some astrophysics projects require access to larger instruments than the 2.4-m TNT, so NARIT scientists and their international collaborators regularly win observing time on 3.6-m and 4-m telescopes in Australia, China and India, and on the 11-m SALT in South Africa.

Meanwhile, NARIT's growing optical team has been busy designing and constructing auxiliary instrumentation (including a coronagraph) for the TNT, and for other NARIT telescopes.

Recently, NARIT's astrophysical research has taken on a distinctly multiwavelength dimension, involving gamma-ray astronomy, neutrino astronomy and radio astronomy. At the time of writing (October 2020) a stand-alone 40-m diameter radio telescope has just been constructed at a mountainous radio-quiet site near Chiang Mai (see Figure 32). It is hoped

> … that eventually there will be three identical dishes in Thailand, in the north, east and south (to maximize baselines), and that these will form a Thai VLBI Network, but also work closely with the existing VLBI networks in East Asia (China, Taiwan, South Korea and Japan) and in Australia-New Zealand. (Orchiston and Swarup 2019: 378).

A growing pool of tenured astronomers, post-doctoral fellows, research assistants and graduate students carry out NARIT's astrophysical research programs, aided by the Thai Government which provided funding so that students can study overseas for their PhD degrees in astronomy. Most of these graduates return to Thailand, some to posts at NARIT and others to the many universities that now teach astronomy.

As part of its national role, NARIT has been promoting astrophysical research and research collaborations at these universities, and in July 2007 it signed memorandums of understanding with 24 different Thai universities. Meanwhile, at an international level, NARIT also has similar arrangements with various universities, observatories and research institutes in more than 15 countries (Soonthornthum, 2017).

Professor Soonthornthum also was keen to foster astronomical research among SE Asian nations, and following a meeting in 2007 he formed SEAAN, the South East Asia Astronomy Network. The goals of this network are

> … to establish strong research collaborations, identify key science appropriate to the region, share instruments and develop and utilize human resources among South-East Asian countries. The network now has annual meetings in different cities throughout the region, and acts as a regional platform to bring the advancement in astronomy to each member country. Research collaborat-

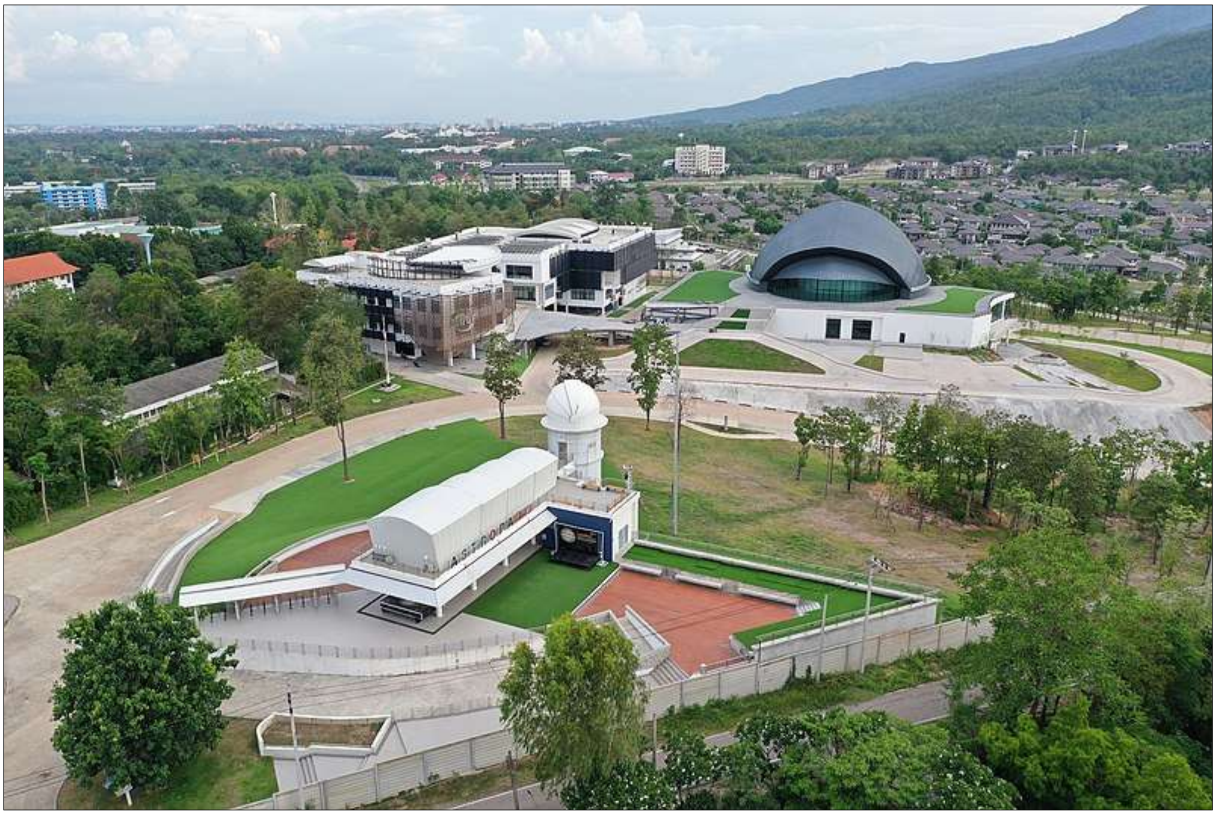


Figure 33: An aerial view of the new NARIT headquarters, the Princess Sirindhorn AstroPark, in outer suburban Chiang Mai. In the foreground is the public observatory, and behind it (with the grey two-stage domed roof) is the planetarium and exhibition building. To the left of this is the multi-storey building with staff offices, a library and archives, meeting rooms, optical laboratories, etc. Behind this building, and partly hidden from view, are the workshops and further laboratories (Wikipedia Commons).

ions have been organized or are planned in optical and radio astronomy, in the development of instrumentation, and in history of astronomy, not just within the SEAAN region, but also with institutes in Australia, China, India, Japan, Korea and Taiwan. (Soonthornthum, 2017: 289).

The SEAAN History and Heritage Working Group, which was founded and is Chaired by the first author of this paper, has been particularly active. It has already organized three mini-conferences that attracted astronomers from SEAAN nations (but mainly Indonesia, Malaysia, the Philippines, Thailand and Vietnam), and also from Australia, India, Japan, Scotland, Sweden and the USA. Some of the papers presented at these Working Group Conferences appeared in the following book, which was published by Springer in 2021: *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities* (Orchiston and Vahia, 2021).

Thus far our focus on NARIT has primarily been on research and instrumentation, but NARIT also has been very active in schools education and public outreach, promoted by a large pool of staff with university training in astronomy. NARIT now occupies a new expansive landscaped headquarters precinct on the north-eastern outskirts of suburban Chiang Mai, which includes a planetarium, astronomy displays, and a public observatory (see Figure 33).

In addition to catering to the needs of Chiang Mai schools, members of the general public and visitors to the city, NARIT takes astronomy to a national audience through a growing network of regional observatories. Currently there are three of these, at Songkhla, Nakhon Ratchasima and Chachoengsao (see Figure 34), with more planned. Each regional observatory is staffed by trained astronomers, and includes a planetarium, lecture rooms and a public observatory with a 0.7-m telescope and an assemblage of smaller telescopes. By way of example, Figure 35 shows the Chachoengsao Regional Observatory to the east of Bangkok.

Without doubt, one of the primary reasons for the astounding developments in Thai astronomy that have occurred over the past decade was the strong support of the late King

Bhumipol Adulyadej (Rama IX; 1927–2016; Figure 36) and his second daughter, Princess Maha Chakri Sirindhorn (Figure 37),

> … both of whom have been passionate about astronomy. This follows a long-standing Royal tradition that began with King Narai, and had circumstances been different it is possible that the late King would have become a professional astronomer. Meanwhile Princess Sirindhorn is an avid 'eclipse-chaser', and also makes observations

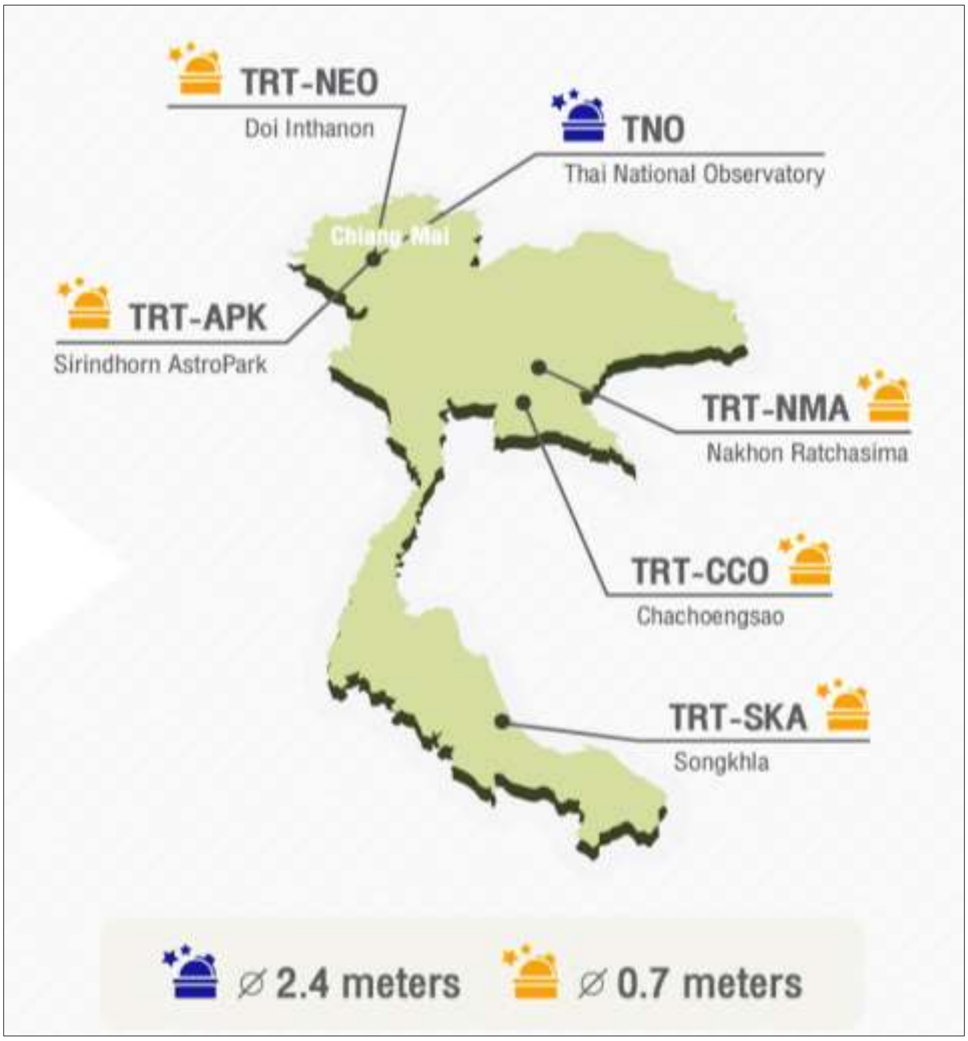


Figure 34: A map of Thailand showing the location of the Thai National Observatory (TNO) and NARIT headquarters at the Princess Sirindhorn AstroPark in northern Thailand, and the current distribution of regional observatories (courtesy: NARIT).

Figure 35: A panoramic view of the Chaocheongsao Regional Observatory, showing the main building with the planetarium, and on the left the observatory (courtesy: NARIT).

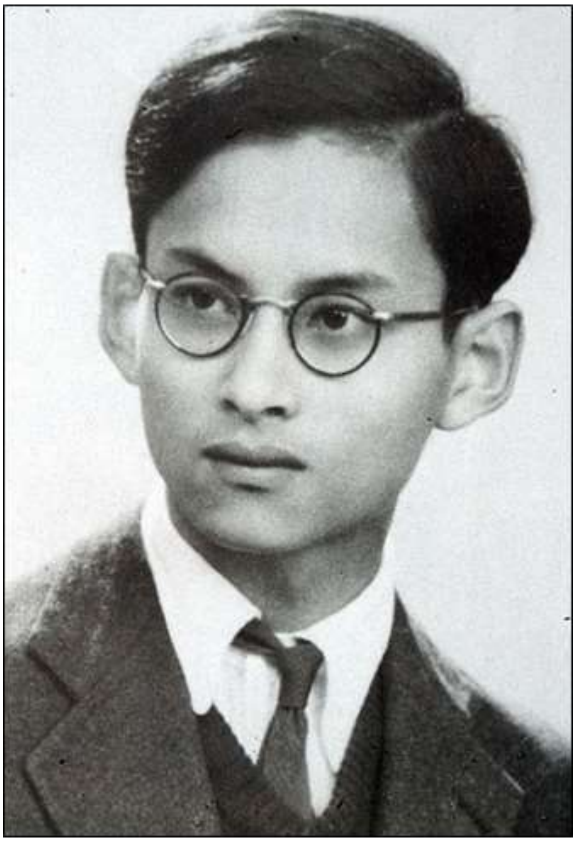


Figure 36 (left): King Bhumipol Adulyadej (Rama IX) as a young man (Wikimedia Commons).

Figure 37 (right): Her Royal Highness Princess Maha Chakri Sirindhorn (https://www.bangkokpost.com/thailand/general/1753149/china-gives-princess-top-award#group=nogroup&photo=0

and carries out astrophotography with various NARIT telescopes (including the 2.4-m Thai National Telescope [e.g. see Figure 38]). (Orchiston et al., 2019: 210).

Figure 38: An image of Jupiter captured by HRH Princess Maha Chakri Sirindhorn using the 2.4-m Thai National Telescope (after Anonymous, 2014: [vii]).

Finally, since this paper is from a conference about historical observatories, perhaps we should end this overview of NARIT by briefly describing the research in history of astronomy that has been carried out by NARIT staff and their Thai and international collaborators. At the time of writing (October 2020) the NARIT History of Astronomy research collaboration was one of the largest in the world, and numbered more than 60 individuals. They derived from Argentina (1), Australia (7), Belgium (1), China (2), France (3), Germany (1), Honduras (1), India (9), Indonesia (6), Japan (4), New Zealand (7), Philippines (4), South Korea (4), Sweden (1), Thailand (3) and the USA (9). Although the research was wide-ranging, much of it related to six discrete themes:

(1) Seventeenth century Jesuit astronomy (Philippines, Siam)
(2) Early radio astronomy (Australia, India, Japan and New Zealand)
(3) Historic solar eclipses (Aden, India, Indonesia, Malaysia, New Zealand, Siam)
(4) Ethnoastronomy (India, Indonesia, New Zealand, Philippines)
(5) Development of astrophysics (Australia,

Figure 39: Examples of three recent covers of the *Journal of Astronomical History and Heritage*.

China, India, New Zealand, South Korea)
(6) Cometary and meteor astronomy (Australia, India, New Zealand)

The group had a strong record of publication: from (and including) 2015 there were 64 published papers, many book reviews and 13 books authored or edited with NARIT affiliations. A further 21 papers 'in press' were scheduled to appear in 2021.[2]

The group published many of its research papers in the *Journal of Astronomical History and Heritage* (see Figure 39), an open access e-journal and one of only two professional history of astronomy journals in the world. This journal was co-founded by the first author of this paper in 1998, was edited by him, and was posted on the NARIT web site. From 2021 four issues per year were planned, each of 200–250 pages.[3] .

6 CONCLUDING REMARKS

During the nineteenth century, Western colonialism brought 'modern astronomy' to present-day India, Myanmar, Singapore, Vietnam, Indonesia, the Philippines, Australia and New Zealand. Government-funded observatories were found at Bombay (now Mumbai), Madras (now Chennai) and Trivandrum (now Thiruvananthapuram) in India; at Rangoon (now Yangon) in Myanmar; at Singapore; at Haiphong in Vietnam; at Batavia (now Jakarta) and Surabaya in Indonesia; at Perth, Adelaide, Hobart, Melbourne, Sydney and Brisbane in Australia; and at Wellington in New Zealand (for localities mentioned see Figure 40). There also were Jesuit-funded observatories in Calcutta (India), Manila (Philippines) and in Sydney, as part of their long-standing commitment to astronomy and a worldwide network of observatories (see Udias, 2003). Meanwhile, private observatories maintained by amateur astronomers peppered the British colonies of India (see Kapoor, 2014; 2020; Kochhar and Orchiston 2017), Australia (Orchiston, 1985b, 1988b, 1992, 2001, 2015, 2017; Orchiston and Brewer, 1990) and New Zealand (Hearnshaw and Orchiston, 2017; Orchiston, 2016).

The professional observatories in Bombay, Rangoon, Singapore, Surabaya, Hobart, Brisbane and Wellington) were rather modest affairs and in most instances little more than transit observatories connected to a time ball that provided a local time service as well as meteorology information. In stark contrast, the more substantial observatories in Trivandrum, Madras, Batavia, Perth, Adelaide, Melbourne and Sydney also addressed various combinations of geomagnetism (particularly in India), seismology (e.g. at the Jesuit Riverview Observatory in Sydney), tidal studies (initially at Sydney Observatory), trigonometrical surveys (until they were jettisoned by Australian and Indian observatories), and astronomical research (especially at Madras, Perth, Adelaide, Melbourne and Sydney Observatories). In the last quarter of the century astronomers at Poona (now Pune) in India (Ansari, 2019), at Melbourne and Sydney Observatories in Australia (Orchiston et al., 2017), and Professor Bickerton in Christchurch, New Zealand (Gilmore, 2017), all ventured into the 'new astron-

Figure 40: Indian, SE Asia, Australian and New Zealand localities mentioned in the text. The orange bull's eye marks Siam (*aka* Thailand), and ASEAN nations are shown in green (map modifications: Wayne Orchiston).

omy', astrophysics, which applied photography and spectroscopy to astronomical issues (e.g. see Hearnshaw, 2009; Hughes, 2013; Nakamura and Orchiston, 2017). The Government-funded Nizamiah Observatory in Hyderabad also made extensive use of photography when it joined the Cart du Ciel and International Astrographic Project (Kochhar and Orchiston, 2017). Meanwhile, the 1874 transit of Venus and the 1898 total solar eclipse inspired the founding in India of observatories at Kodaikanal, Calcutta and Dehra Dunn that specifically focused on solar astronomy, in a quest for information that might help prevent or alleviate droughts (see Chinnici, 1995/96; Kochhar and Orchiston, 2017).

Nineteenth century Siam was very different. There was no professional astronomy and neither King Rama VI nor King Rama V felt the need to establish a National Observatory. Nor was there a Jesuit astronomical presence in Siam at this time. The Siamese population was committed to Buddhism, with its astrological rather than astronomical overtones, or—mainly in the south—to Islam, where astronomy provided a calendar and times for prayers but little else. Otherwise, serious observational astronomy was seen as the exclusive domain of the King, interested members of the Royal Family, and expatriates like Henry Alabaster and Captain Loftus who assisted with the eclipse expeditions of 1868 and 1875. Unlike the Asian–Oceanic British colonies, with the notable exception of the Swiss engineer, Henri Brändli (Lequeux, 2023: 185–186), Siam lacked amateur astronomers, indigenous or expatriate, who liked to observe the Sun, the Moon, the planets, eclipses, lunar occultations, comets, double stars and variable stars, and publish their observations in newspapers, local scientific journals and in international astronomical journals. Consequently, major international events like the 1874 and 1882 transits of Venus received scant attention in Siam, unlike in the British colonies of India, Australia and New Zealand where they were viewed, written about and used to popularize astronomy by many committed amateur astronomers (see Kapoor, 2014; Orchiston, 2004; and Orchiston, 2016: 371–419, respectively). Meanwhile, compare the 1868 and 1875 total solar eclipses, which were exclusively researched and written up by Western scientists visiting Siam (see Section 4, above), with the 9 September 1885 total solar that was viewed by thousands of residents across central New Zealand (Orchiston, 2016: 447–479) and researched, photographed and written about by many New Zealand amateur astronomers (Orchiston and Rowe, 2017).

Siam also lacked a Ragoonatha Charry, the Indian astronomer employed by Madras Observatory, who conducted research (Kameswara Rao et al., 2009) and wrote monographs in local languages that explained important astronomical events, such as the 1874 transit of Venus. Charry was committed to providing Western scientific explanations in a bid to reduce the hold of astrology and superstition. (Shylaja, 2012; Venkateswaran, 2019). In Siam, only King Rama IV attempted to do this (for example, see Soonthornthum and Orchiston, 2021).

As we have seen, late in the nineteenth century astrophysics made its first appearance in South Asia, Australia and New Zealand, but no Siamese citizens or expatriates decided to experiment with this 'new astronomy', and it is even possible that King Rama V was unaware of major developments that were taking place in this field. If he did, perhaps he considered them irrelevant in the context of Siam's modernization.

So much for Siamese astronomy during the nineteenth century. How did meteorology, geomagnetism, seismology and trigonometrical surveys fare vis-à-vis the British colonial observatories model?

Siamese people had access to a time service, but it was local, not national, and was based upon traditional time-keeping methods. The impressive-looking Royal Clock Tower was King Rama IV's indulgence and a political statement, not the bastion of a professional national time service. This was very different from the colonial role model, which also was tied to supplying a time service for shipping and the regulation of chronometers (see Kinns, 2022). Unlike Australia and New Zealand, Siam experienced no nineteenth-century gold rushes that saw an avalanche of immigrants, and a concomitant exponential increase in coastal shipping. In Siam, time was a private matter, tied mainly to rural and urban life.

Meteorology also followed a distinctly non-colonial path in Siam, its introduction coming late—at the end of the century—and then only in the service of the Royal Siamese Navy and navigation. Unlike Australia and New Zealand, there was no need to predict weather conditions as an aid to the successful spread of Western farming, or to monitor the monsoons, droughts and floods, which were the life-blood of rural India. The seasons were more predictable in Siam than in India, lessening the need for meteorological data, and as Williamson (2015, 2020) has shown, this also was a factor in the British decision not to focus on meteorology in neighboring colonial Malaya. Similar logic applied to Burma, whereas French and Spanish colonial possessions to the east of Siam had a very different meteorological imperative to address: the threat of cyclones. Here international communication was critical, and Williamson and Wilkinson (2017: 161) stress that

> The laying of electric telegraph across the mid-to-late nineteenth century played a major role here, making possible the rapid transmission of news … [then] After 1915, radio telegraphy was used to communicate between shipping and the mainland …

Meanwhile, as we have seen, meteorology in the service of farming and rice cultivation only emerged in Siam during the twentieth century.

Nor were seismology and geomagnetism deemed necessary in nineteenth century Siam, which was not seen as an earthquake-prone nation and, unlike in British India and Australia—or even the Dutch East Indies with its Royal Magnetic and Meteorological Observatory in Batavia (Hidayat et al., 2017)—was not party to Sabine's 'geomagnetic crusade'. Had there been a National Observatory in Siam at the time then the outcome could have been very different given the close diplomatic relations that Kings Rama IV and V maintained with Britain. And unlike in colonial India and the Dutch East Indies (Hidayat, 2000; Orchiston et al., 2021c), there was no urgent need for trigonometrical and cadastral surveying in

Siam until the widespread reforms initiated by King Rama V and changes in national boundaries following the ceding of land to Britain and France.

Royal domination of astronomy, a nation wedded mainly to Buddhism and Islam, and Siam's independence were the primary factors that prevented the formation of a National Astronomical Observatory in Siam during the nineteenth century. And whereas Pyenson (1987) saw the emergence of professional astronomy in the Dutch East Indies as a clash between metropolitan aspirations on the one hand and colonial endeavors on the other, independent Siam had to contend with neither.

Instead, the total solar eclipse of 1929 eclipse was the catalyst that led to the launch of 'modern astronomy' in Siam and Thailand and the eventual appearance of professional astronomy and astronomical observatories.

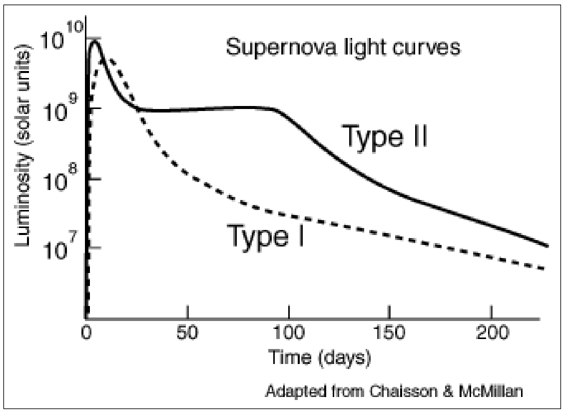


Figure 41: Typical light curves of Type I and Type II supernovae. If we read Time in years from 2009 (instead of days) and Total Budget on the y-axis (instead of Luminosity), in 100 years time will the evolutionary path of Thailand astronomy follow either of these light curves? (diagram: http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/snovcn.html).

It was this eclipse which produced a Siamese national (Colonel Nides), not an expatriate, interested in teaching Western astronomy at university. The eclipse also attracted an emerging Thai middle class with the time and finances to indulge in a Western-style education and the ability and willingness to differentiate between the dictates of 'scientific astronomy' and Buddhist astrology. Even so, the emergence of professional astronomy in Thailand was slow, bolstered mainly by the teaching and research developments at Chiang Mai University.[4]

Following the landmark solar eclipses of 1868 and 1875, Thailand was only once more able to achieve international astronomical visibility with the founding and development of NARIT, and this in no small part was thanks to Royal patronage. So, in this instance Royal interest nourished the growth of professional astronomy, instead of stifling it (as during the reigns of Kings Rama IV and V). Then in 2009 NARIT exploded onto the local and international astronomical landscape like a supernova. This precipitated an astronomical revolution throughout Thailand, especially in the universities, and through the rapid growth of amateur astronomy. Yet supernovae have predictable light-curves (see Figure 41). What, we may wonder, will history tell us about the evolution of Thai astronomy one hundred years from now?

6 NOTES

1. Doi Inthanon is Thailand's highest mountain, at 2,565 metres. By road, it is about 90 km west-southwest of Chiang Mai.
2. However, the current situation is very different. When the first author's 2020–2021 contract with NARIT ended on 30 September 2021 for reasons that were never divulged it was not renewed. In consequence, NARIT's international history of astronomy collaborations were disbanded.

   However, as of the date of this publication (i.e. May, 2023) there is a new history of astronomy group at NARIT. It appears that its collaborations currently are only with Chiang Mai University; research is restricted to the Thai calendar and Buddhist and Kymer temple alignments; and the publications output is modest. Sadly, NARIT no longer has an international profile in history of astronomy research, and it seems there is no attempt to place Thai history of astronomy in a SE Asian—let alone an Asian–Oceanic—context.
3. When the first author of this paper (WO) left NARIT the future of the *Journal of Astronomical History and Heritage (JAHH)* was under threat, but thanks to international support it survived. On 1 August 2022 ownership of *JAHH* was transferred to the University of Science and Technology of China, in Hefei, and they employed WO as a Co-Editor.

   Since NARIT severed its links with the Journal, *JAHH* has continued to develop, and it now features two new Sections, 'Reminiscences' and 'From the Archives'. *JAHH* remains an open access e-journal, with four issues per year. There are no page charges, and back numbers are freely available on the ADS, Rizal Technologi-

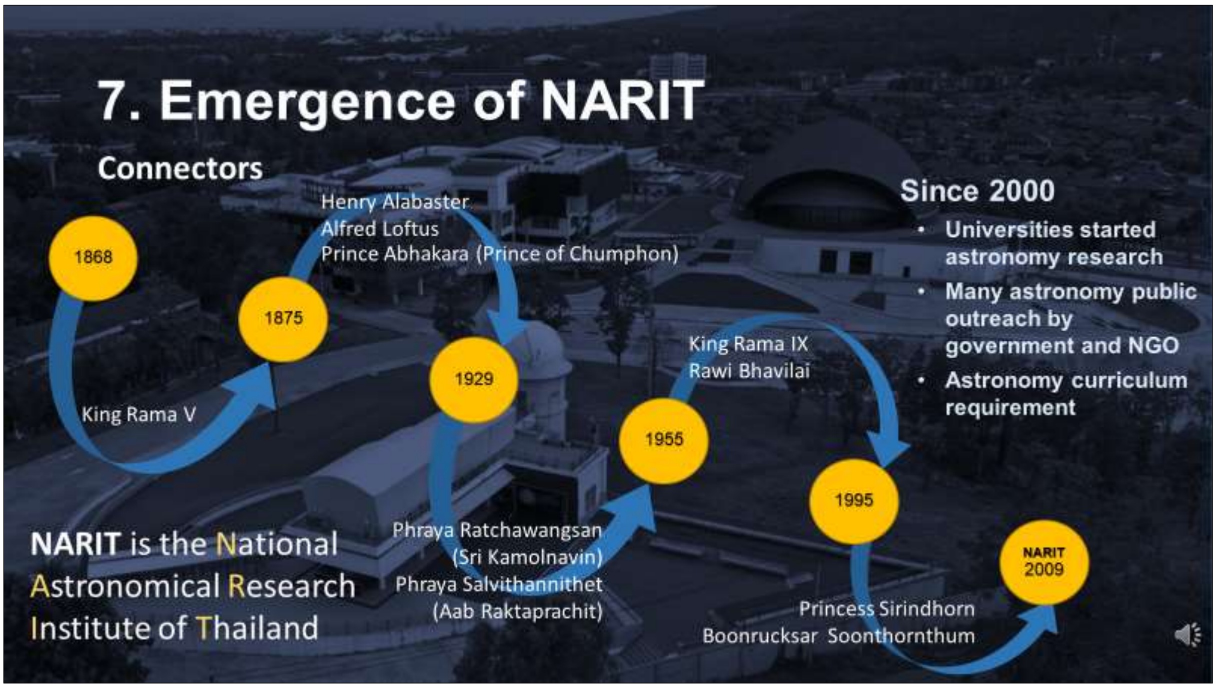


Figure 42: A diagram showing the 'Connectors' who collectively were largely responsible for the evolution of Siamese and Thai astronomy between 1868 and 2009 (after Euarchukiati et al., 2022).

ical University and the *JAHH* web sites. The URL of this last-mentioned site is: http://jahh.ustc.edu.cn

4. Recently, Euarchukiati et al. (2022) have highlighted the special roles that 'Connectors', that is, certain individuals, played in this evolutionary process between 1868 and 2009—see Figure 42.

8 ACKNOWLEDGEMENTS

We are very grateful to the SEASREP Foundation Inc. and the Ynchausti Foundation for kindly funding our attendance at the February 2020 conference "Where Science and Empire Met: Observatories in Asia in the Late 19th to Mid–20th Centuries" just before the COVID–19 Philippines lockdown occurred, and especially to Nikolas Ynchausti, Professor Maris Diokno and Dr Kerby Alvarez UP (University of the Philippines, Diliman) for their support and encouragement.

We also wish to thank Visanu Euarchukiati (Bangkok) for supplying data used in this paper, and the National Astronomical Research Institute of Thailand, King Prajadhipok Museum (Bangkok), the Observatoire de Marseille Archives, Office of the National Research Council of Thailand, the Royal Astronomical Society and the late Dr Harley Wood for kindly providing Figures 4, 5, 18, 20, 24–26, 30–32 and 34–35.

8 REFERENCES

Alvarez, K.C., 2020. Observing heavens, marking time: the astronomical work of the Observatorio Meteorológico de Manila, later reorganized as the Philippine Weather Bureau, 1891–1945. *Journal of Astronomical History and Heritage*, 26(1), 9–30.

Andropoulos, J., 2014. The Astronomical Publications of Melbourne Observatory. Doctoral dissertation, Faculty of Science, James Cook University, Townsville, Australia.

Anonymous, 1899. The late Alfred J. Loftus, F.R.G.S. *Handsworth* 6, 63, 1–3.

Anonymous, 1900. Meteorological Department. The Observatory. In *Cyclopedia of Tasmania* ... Hobart, Maitland and Krone.

Anonymous, 2008. Knowledge without bounds. *Lumen* [The University of Adelaide Magazine], Winter issue.

Anonymous, 2014. *Annual Report 2013. National Astronomical Research Institute of Thailand (Public Organization)*. Chiang Mai, National Astronomical Research Institute of Thailand.

Anonymous, 2017a. Prominent astronomer Prof Rawi dies. *Bangkok Post*, 17 March.

Anonymous, 2017b. Rawi Bhavil. Australian National University. (https://rsaa.anu.edu.au/people/alumni/rawi-bhavilai; retrieved 5 November 2020).

Ansari, S.M.R., 2000. Introduction of modern Western astronomy in India during 18th–19th centuries. In Sen, S.N., and Shukla, K.S. (eds.), *History of Astronomy in India*. New Delhi, Indian National Science Academy. Pp. 395–453.

Ansari, S.M.R., 2011. Early modern Observatories in India, 1792–1900. In Das Gupta, U. (ed.), *History of Science, Philosophy and Culture in Indian Civilization. Volume XV, Part 4. Science and Modern India: An Institutional History, c.1784*–1947. Delhi, Pearson Longman. Pp. 349–379.
Ansari, S.M.R., 2019. K.D. Naegamvālā: the founder of the first astrophysical observatory in India. In Orchiston, Sule and Vahia, 307–324.
Aubin, D., 2010. Eclipse politics in France and Thailand, 1868. In Aubin, D., Bigg, C., and Sibim, H.O. (eds.), *The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture*. Durham, Duke University Press. Pp. 86–117.
Bhavilai, R., 1971. *The Fine Structure of the Solar Corona*. Ft. Belvoir (Virginia), Defense Technical Information Center.
Biswas, A.K., 1994. Reverend Father Eugene Lafont and the scientific activity of St. Xavier's College. *Indian Journal of History of Science*, 29, 77–88.
Bobis, L., and Lequeux, J. (eds.), 2012. *L'Observatoire de Paris: 350 Ans de Science.* Paris, Observatoire de Paris.
Bradley, W.L., 1966. Prince Mongkut and Jesse Caswell. *Journal of the Siam Society*, 55, 29–41.
Buckley, B.M., Palakit, K., Duangsathaporn, K., Sanguanthan, P., Prasomsin, P., 2007. Decade scale droughts over northwestern Thailand over the past 448 years: links to the tropical Pacific and Indian Ocean sectors. *Climate Dynamics*, DOI 10.1007/s00382-007-0225-1.
Cawood, J., 1977. Terrestrial magnetism and the development of international collaboration in the early nineteenth century. *Annals of Science*, 34, 551–587.
Chandran, J., 1977. *The Contest for Siam 1889-1902: A Study in Diplomatic Rivalry*. Kuala Lumpur, Penerbit Universiti Kebangsaan Malaysia.
Chinnici, I., 1995/96. An "Italian" observatory in Calcutta: the history of the Calcutta Observatory. *Studies in History of Medicine and Science*, 16, 91–115.
Cushman, G.T., 2013. The imperial politics of hurricane prediction: from Calcutta to Manila and Galveston, 1839–1900. In Bsumek, E.M., Kinkela, D., and Lawrence, M.A. (eds.), *Nation-States and the Global Environment: New Approaches to International Environmental History*. Oxford, Oxford Scholarship Online.
Donnelly, M.C., 1973. *A Short History of Observatories*. Eugene, University of Oregon Press.
Edwards, P.G., 1993. Charles Todd and the Adelaide Observatory. *Proceedings of the Astronomical Society of Australia*, 10, 349–354.
Edwards, P.G., 1994. The Adelaide Observatory after Todd. *Proceedings of the Astronomical Society of Australia*, 11, 206–210.
Ellery, R.J., 1869. *Astronomical Observations Made at the Williamstown Observatory in the Years 1861, 1862, and 1863*. Melbourne, Government Printer.
Espenak, F., and Meeus, J., 2006. *Five Millennium Canon of Solar Eclipses: –1999 to + 3000*. Greenbelt, NASA (Technical Publication TP-2006-214141).
Euarchukiati, V., 2021a. Observations of the 6 April 1875 total solar eclipse from the Grand Palace in Bangkok. In Orchiston and Vahia, 345–372.
Euarchukiati, V., 2021b. The 1875 British solar eclipse expedition to Siam led by Dr Arthur Schuster. In Orchiston and Vahia, 317–343.
Euarchukiati, V., Orchiston, D.L., and Orchiston, W., 2022. Royal Patronage, Total Solar Eclipses and Transitory Western Observatories Led to the Emergence of Professional Astronomy in Thailand. Paper presented at the Annual Conference of the Antique Telescope Society, USA, 13 November, 2022.
Falvey, L., 2001. Thai agriculture from Ayutthaya to the early twentieth century. *Asian Agri-History*, 5, 283–296.
Forbes, E.G., Meadows, A.J., and Howse, D., 1975. *Greenwich Observatory ... the Story of Britain's Oldest Scientific Institution, the Royal Observatory at Greenwich and Herstmonceux, 1675–1975*. Three Volumes. London, Taylor & Francis.
García Herrera, R., Ribera, P., Hernández Martín, E., and Gimeno, L., 2007. Northwest Pacific typhoons documented by the Philippine Jesuits, 1566–1900*. Journal of Geophysical Research–Atmospheres*, 112. ISSN 2169-897X.
Gascoigne, S.C.B., 1992. Robert L.J. Ellery, his life and times. *Proceedings of the Astronomical Society of Australia*, 10, 170–176.
Giblin, R.W., 1904. Lopburi past and present. *Journal of the Siam Society*, 5(3), 8–28.
Giblin, R.W., 1908. Royal Survey work. In Wright, A., and Breakspear, O.T. (eds.), *Twentieth Century Impressions of Siam: Its History, People, Commerce, Industries, and Resources*. London, Lloyd's Greater Britain Publishing Company Ltd. Pp. 121–127.
Giblin, R.W., 1909. Early astronomical and magnetic observations in Siam. *Journal of the Siam Society*, 6(2), 1–15.
Gillespie, R., 2011. *The Great Melbourne Telescope*. Melbourne, MuseumVictoria.
Gilmore, G.F., 2017. Alexander William Bickerton: New Zealand's first astrophysicist? In Nakamura and Orchiston, 2017b, 623–640.
Gislén, L., Launay, F., Orchiston, W., Orchiston, D.L., Débarbat, S., Husson, M., George, M., and Soonthornthum, B., 2018. Cassini's 1679 map of the Moon and French Jesuit observations of the lunar eclipse of 11 December 1685. *Journal of Astronomical History and Heritage*, 21, 211–225.
Grabowsky, V., 2017. Population dynamics in Lan Na during the 19th century. *Journal of the Siam Society*, 105, 197–244.
Hall, D.G.E., 1981. *A History of Southeast Asia*. London, Macmillan.

Hallett, H., 1890. *A Thousand Miles on an Elephant in the Shan States.* Edinburgh, Blackwood (reprinted 1988. Bangkok, White Lotus).
Haynes, R.D., Haynes, R.A., and Kitson, W.S., 1993. The history of astronomy in Queensland. *Vistas in Astronomy*, 36, 231–252.
Hearnshaw, J., 2009. *The Analysis of Starlight: One Hundred and Fifty Years of Astronomical Spectroscopy*. *Second Edition*. Cambridge, Cambridge University Press.
Hearnshaw, J., and Orchiston, W., 2017. The development of astronomy and emergence of astrophysics in New Zealand. In Nakamura and Orchiston, 2017b, 581–621.
Henry Alabaster. n.d. (https://en.wikipedia.org/wiki/Henry_Alabaster#:~:text=Alabaster%20first%20came%20to%20Siam,in%20Thailand%2C%; retrieved 5 November 2020).
Herschel, Sir John F.W., 1859. *Outlines of Astronomy. Sixth Edition*. London, Longman, Green, Longman and Roberts.
Hidayat, B., 2000. Under a tropical sky: a history of astronomy in Indonesia. *Journal of Astronomical History and Heritage*, 3, 45–58.
Hidayat, B., Malasan, H.L., and Mumpuni, E.S., 2017. The development of astronomy and emergence of astrophysics in Indonesia. In Nakamura and Orchiston, 2017b, 329–356.
Hughes, S., 2013. *Catchers of the Light. The Forgotten Lives of the Men and Women who First Photographed the Heavens. Their True Tales of Adventure, Adversity & Triumph.* Two Volumes. Paphos, ArtDeCiel Publishing.
Hutchison, D., 1980. William Ernest Cooke: first Government Astronomer. *Early Days*, 8, 93–114.
Hutchison, D., 1981. William Ernest Cooke, astronomer 1863-1947. *Historical Records of Australian Science*, 5, 58–77.
Illustrated London News, 19 June (1875).
Kameswara Rao, N., Vagiswari, A., Thakur, P., and Birdie, C., 2009. Ragoonatha Charry and variable star astronomy. *Journal of Astronomical History and Heritage*, 12, 201–210.
Kapoor, R.C., 2014. Indian astronomy and the transits of Venus. 2: The 1874 event. *Journal of Astronomical History and Heritage*, 17, 113–135.
Kapoor, R.C., 2020. Comet tales from India: the Great September Comet of 1882 (C/1882 R1). *Journal of Astronomical History and Heritage*, 23, 353–374.
Kapoor, R.C., and Orchiston, W., 2023a. Colonial astronomy as an element of Empire in British India. *Journal of Astronomical History and Heritage*, 26(1), 113–158.
Kapoor, R.C., and Orchiston, W., 2023b. Independent Indian initiatives to establish 'Western' astronomical observatories prior to independence. *Journal of Astronomical History and Heritage*, 26(3), in press.
King, T., 1902. On New Zealand Mean Time, and on the longitude of the Colonial Observatory, Wellington; with a note on the Universal Time question. *Transactions and Proceedings of the Royal Society of New Zealand*, 35, 428–451.
Kinns, R., 2009. Time-keeping in the Antipodes: a critical comparison of the Sydney and Lyttelton time balls. *Journal of Astronomical History and Heritage*, 12, 97–107.
Kinns, R., and Abell, L., 2009. The contribution of Maudslay, Sons & Field to the development of time balls in Australia. *International Journal for the History of Engineering & Technology*, 79, 59–90.
Kinns, R., 2011. The Hobart time ball and time gun: a critical review. *Journal of Astronomical History and Heritage*, 14, 145–164.
Kinns, R., 2017. The principal time balls of New Zealand. *Journal of Astronomical History and Heritage*, 20, 69–94.
Kinns, R., 2020. Time signals for mariners in India, Burma and Ceylon. *Journal of Astronomical History and Heritage*, 23, 523–552.
Kinns, R., 2021. Time signals for mariners in SE Asia: time balls, discs, bells, guns and lights. In Orchiston and Vahia, 411–458.
Kinns, R., 2022. Visual time signals for mariners between their introduction and 1947: a new perspective. *Journal of Astronomical History and Heritage*, 25(4), 601–713.
Kochhar, R.K., 1991. Astronomy in British India: science in the service of the state. *Current Science*, 60, 120–129.
Kochhar, R., and Orchiston, W., 2017. The development of modern astronomy and emergence of astrophysics in India. In Nakamura and Orchiston, 2017b, 705–770.
Kosuwan, S., Takashima, I., and Charusiri, P., n.d. Active fault zones in Thailand. Department of Mineral Resources, Thailand (http://www.dmr.go.th/main.php?filename=fault_En; retrieved 5 November 2020).
Kramer, B., 2007. Astronomy in Thailand. In Hearnshaw, J., and Martinez, P. (ed.), *IAU Special Session #5. Astronomy for the Developing World*. *26th Meeting of the IAU, held 21–22 August, 2006 in Prague, Czech Republic. IAU Special Session No. 5, 2006*. Cambridge, Cambridge University Press. Pp. 123–128.
Krukthong, P.S., 2019. Where did the idea to build a tall tower to tell the time in Siam come from? *History Art Culture* (https://www.silpa-mag.com/history/article_37344; retrieved 5 November 2020).
Lardner, D.C.L., 1853–1856. *Handbook of Astronomy. Volume II*. London, Walton and Mabery.
Launay, F., 2012. *The Astronomer Jules Janssen: A Globetrotter of Celestial Physics*. New York, Springer.
Lequeux, J., 2023. The total solar eclipse of 9 May 1929: the French expeditions to Poulo Condor Island in French Indochina. *Journal of Astronomical History and Heritage*, 26(1), 179–187.
Lomb, N., 2011. *Transit of Venus: 1639 to the Present*. Sydney, NewSouth and Powerhouse Museum.

Lord, D.C., 1969. *Mo Bradley and Thailand*. Grand Rapids, William B. Eerdmans Publishing Company.
McCarthy, J., 1900. *Surveying and Exploring in Siam*. London, John Murray.
McGregor, P.M., 1979. Australian magnetic observatories. *B.M.R.J. Australian Journal of Geology and Geophysics*, 4, 361–371.
Moffat, A.L., 1961. *Mongkut, the King of Siam*. Ithaca, Cornell University Press.
Mumpuni, E.S., Orchiston, W., and Steinicke, W., 2017. J.A.C. Oudemans' observations of the 18 August 1868 and 12 December 1871 total solar eclipses from the Dutch East Indies. In Nakamura and Orchiston, 2017b, 357–373.
Nakamura, T., and Orchiston, W., 2017a. Introduction. In Nakamura and Orchiston, 2017b, 1–22.
Nakamura, T., and Orchiston, W. (eds.), 2017b. *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe*. Cham (Switzerland), Springer.
Nath, B.B., 2013. *The Story of Helium and the Birth of Astrophysics*. New York, Springer.
Nath, B.B., and Orchiston, W., 2021. Norman Robert Pogson and the observation of the total solar eclipse of 1868 from Masulipatam, India. *Journal of Astronomical History and Heritage*, 24(3), 629–651.
Neumayer, G., 1858. Description and system of working of the Flagstaff Observatory. *Transactions of the Philosophical Society of Victoria*, 3, 94–103.
Noor, N.A.B.M., and Orchiston, W., 2021. The total solar eclipse of 9 May 1929: the British expedition to Alor Star in the Unfederated Malay State of Kedah. In Orchiston and Vahia, 391–410.
O'Connell, D.K.J., 1952. Father Edward Francis Pigot, S.J. *Studies*, 1, 189–196; 2, 323–332.
Ôhashi, Y., and Orchiston, W., 2021. The evolution of local Southeast Asian astronomy and the influence of China, India, the Islamic World and the West. In Orchiston and Vahia, 673–767.
Orchiston, W., 1985a. Life-history of a telescope: the 17.8-cm refractor at the Riverview Observatory in Sydney. *Australian Journal of Astronomy*, 1, 57–80.
Orchiston, W., 1985b. The contribution of Alfred Barrett Biggs to Australian and Tasmanian Astronomy. *Records of the Queen Victoria Museum*, 89, 1–28.
Orchiston, W., 1988a. From research to recreation: the rise and fall of Sydney Observatory. *Vistas in Astronomy*, 32, 49–63.
Orchiston, W., 1988b. Illuminating incidents in Antipodean astronomy: Phillip Parker King and the founding of Sydney Observatory. *Vistas in Astronomy*, 32, 285–301.
Orchiston, W., and Brewer, A., 1990. David Ross and the development of amateur astronomy in Victoria. *Journal of the British Astronomical Association*, 100, 173–181.
Orchiston, W., 1992. The contribution of Francis Abbott to Tasmanian and Australian astronomy. *Vistas in Astronomy*, 35, 315–344.
Orchiston, W., 1998. Mission impossible: William Scott and the first Sydney Observatory directorship. *Journal of Astronomical History and Heritage*, 1, 21–43.
Orchiston, W., 2001. William John Macdonnell and the development of astronomy in New South Wales. *Journal of the British Astronomical Association*, 111, 13–25.
Orchiston, W., 2004. The nineteenth century transits of Venus: an Australian and New Zealand overview. *Journal of Astronomical Data*, 10, 219–308.
Orchiston, W., 2015. The amateur-turned-professional (ATP) syndrome: two Australian case studies. In Orchiston, W., Green, D.A., and Strom, R. (eds.), *New Insights from Recent Studies in Historical Astronomy: Following in the Footsteps of F. Richard* Stephenson*.* New York, Springer. Pp. 259–350
Orchiston, W., 2016. *Exploring the History of New Zealand Astronomy: Trials, Tribulations, Telescopes and Transits*. Cham (Switzerland), Springer.
Orchiston, W., Orchiston, D.L., George, M., and Soonthornthum, B., 2016. Exploring the first scientific observations of lunar eclipses made in Siam. *Journal of Astronomical History and Heritage*, 19, 25–45.
Orchiston, W., 2017. *John Tebbutt: Rebuilding and Strengthening the Foundations of Australian Astronomy*. Cham (Switzerland), Springer.
Orchiston, W., Clarke, B.A.J., Frew, D., and Andropoulos, J., 2017. The development of astronomy and the foundations of astrophysics in Australia. In Nakamura and Orchiston, 2017b, 395–452.
Orchiston, W., and Orchiston, D.L., 2017. King Rama IV and French observations of the 18 August 1868 total solar eclipse from Wah-koa, Siam. In Nakamura and Orchiston, 2017b, 291–317.
Orchiston, W., and Rowe, G., 2017. New Zealand astronomy and 9 September 1885 total solar eclipse. In Nakamura and Orchiston, 2017b, 641–673.
Orchiston, W., Orchiston, D.L., George, M., Soonthornthum, B., Gislén, L., Débarbat, S., and Husson, M., 2019. The role of eclipses and European observers in the development of 'modern astronomy' in Thailand. In Orchiston, Sule and Vahia, 173–216.
Orchiston, W., Sule, A., and Vahia, M. (eds.), 2019. *The Growth and Development of Astronomy and Astrophysics in India and the Asia–Pacific Region*. *ICOA–9, Pune, India, 15–18 November 2016*. New Delhi, Hindustan Book Agency and Springer Nature.
Orchiston, W., and Swarup, G., 2019. The emergence of radio astronomy in Asia: opening a new window on the Universe. In Orchiston, Sule, and Vahia, 325–383.
Orchiston, W., Dumon, P., Gislén, L., Orchiston, D.L., George, M., Launay, F., Débarbat, S., Husson, M., and Soonthornthum, B., 2021a. Father Antoine Thomas and the birth of 'modern astronomy' in Thailand. In Orchiston and Vahia, 225–252.
Orchiston, W., Guido, R., Bautista, R.A., Dela Cruz, R.A., Torres, J., and Orchiston, D.L., 2021b. Exploring the history of Philippine astronomy: Catholics, comets, eclipses and ethnohistory. In Orchiston and Vahia, 37–115.

Orchiston, W., Mumpuni, E.S., and Steinicke, W., 2021c. J.A.C. Oudemans and nineteenth century astronomy in the Dutch East Indies. In Orchiston and Vahia, 285–315.

Orchiston, W., and Orchiston, D.L., 2021. King Rama IV, Sir Harry Ord and the total solar eclipse of 18 August 1868: power, politics and astronomy. *Journal of Astronomical History and Heritage*, 24(2), 389–404.

Orchiston, W., Orchiston, D.L., Gislén, L., George, M., Soonthornthum, B., Launay, F., Débarbat, S., and Husson, M., 2021d. Show-casing seventeenth-century Jesuit astronomy in Asia: the lead up to the first scientific observations of a solar eclipse made in Siam. *Journal of Astronomical History and Heritage*, 24(2), 498–520.

Orchiston, W., and Vahia, M. (eds.), 2021. *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities*. Cham (Switzerland), Springer.

Orchiston, W., Orchiston, D.L., George, M., Soonthornthum, B., and Komonjinda, S., 2022. Seventeenth century Jesuit astronomical activities in Siam. In Shi, Y.-L., and Chu, F.L. (eds.), *Astronomical Heritages in Asia–Pacific Areas: Proceedings of the Eighth International Conference on Oriental Astronomy*. Hefei, University of Science and Technology of China. Pp. 89–112.

Ornthammarath, T., Warnitchai, P., Worakanchana, K., Zaman, S., Sigbjornsson, R., and Lai, C.G., 2010. Probabalistic seismic hazard assessment for Thailand. *Bulletin of Earthquake Engineering*, DOI 10.1007/s10518-010-9197-3.

Ornthammarath, T., 2019. Seismic damage to ancient monuments in Chiang Saen (Northern Thailand): implication for historical earthquake in Golden Triangle area. *Philosophical Transactions of the Royal Society A*, https://doi.org/10.1098/rsta.2018.0255.

Owen, N.G. 1971. The rice industry of mainland South East Asia 1850–1914. *Journal of the Siam Society*, 59, 75–143.

Pailiplee, S., and Charusiri, P., 2016. Seismic hazards in Thailand: a compilation and updated probabalistic analysis. *Earth, Planets and Space,* 69, article 98.

Pallegoix, J.B., 1977. *Story of Siam*. Translated by S.T. Komonbutra. Bangkok, Progress Publisher.

Pearce, I., 1981. Giblin, Ronald Worthy (1863–1936). In *Australian Dictionary of Biography*, *Volume 8*. Melbourne, Melbourne University Press.

Perdrix, J., 1961. The Melbourne Observatory. *Journal of the Astronomical Society of Victoria*, 14, 19–25, 45–48, 60–64.

Phạm V.L., and Lê, T.L., 2021. A brief history of Vietnamese astronomy and calendars during the reign of the Royal Dynasties. In Orchiston and Vahia, 119–162.

Phillimore, R.H., 1945–1968. *Historical Records of Survey of India. Five Volumes*. Dehra Dun, Survey of India. [1945: *Volume I*; 1950: *Volume 2*; 1954: *Volume III*; 1955: *Volume IV*; 1968: Volume V.]

Phuong, N.T.H., 2023. Servicing the colonial exploitation: the French establishment and management of Phù Liễn Observatory, 1899–1945. *Journal of Astronomical History and Heritage*, 26(1), 69–82.

Pyenson, L., 1989. *Empire of Reason*. Leiden, Brill.

Rastogi, R.B., 1986. Evolution of geomagnetic studies in India. *Indian Journal of Radio & Space Physics*, 15, 356–363.

Ratcliff, J., 2016. Travancore's magnetic crusade: geomagnetism and the geography of scientific production in a princely state. *The British Journal for the History of Science*, 49, 325–352.

Roy, R.D., 1986. The Great Trigonometrical Survey of India in a historical perspective. *Indian Journal of History of Science*, 21, 22–32.

Royal Thai Survey Department n.d. (https://en.wikipedia.org/wiki/Royal_Thai_Survey_Department; retrieved 5 November 2020.

Saibejra, N., 2006. King Mongkut, the Father of Thai Science. In Chen, K.Y., Orchiston, W., Soonthornthum, B., and Strom, R. (eds.), *Proceedings of the Fifth International Conference on Oriental Astronomy Held in Chiang Mai, Thailand, 4–8 October 2004*. Chiang Mai, Chiang Mai University. Pp. 15–18.

Savours, A., and McConnell, A., 1982. The history of the Rossbank observatory, Tasmania. *Annals of Science*, 39, 527–564.

Seitzer, P., 2020. Astronomy at the Old Manila Observatory. Paper presented at the 2020H&H Conference, Recent Developments in Southeast Asian History of Astronomy, National Astronomical Research Institute of Thailand, Chiang Mai, Thailand, 3–5 February 2020.

Shylaja, B.S., 2012. *Chintamani Ragoonatha Charry and Contemporary Indian Astronomy.* Bangalore, Bangalore Association for Science Education and Navakarnataka Publications Private Limited.

Soonthornthum, B., 1993. Astronomy developments in Thailand. In Leung, K.-C., and Nha, I.-S. (eds.), *New Frontiers in Binary Star Research: A Colloquium Sponsored by the U.S. National Science Foundation and the Korean Science and Engineering Foundation, Seoul and Taejon, Korea, November 5–13, 1990*. San Francisco, Astronomical Society of the Pacific. Pp. 455–457.

Soonthornthum, B., 1997. Astronomy in Thailand. In Leung, K.-C. (ed.), *The Third Pacific Rim Conference on Recent Development of Binary Star Research*. San Francisco. Astronomical Society of the Pacific (ASP Conference Series, Volume 130). Pp. 299–302.

Soonthornthum, B., 2001. What can be done with small telescopes. In Batten, A.H. (ed.), *Astronomy for Developing Countries. Proceedings of a Special Session of the XXIV General Assembly of the International Astronomical Union held in Victoria University of Manchester, Manchester, UK, 14–16 August 2000*. San Francisco, Astronomical Society of the Pacific. Pp. 243–249.

Soonthornthum, B., Kramer, B., and Poshyachinda, S., 2007. Astronomy development in Thailand: the role of NARIT. In Hearnshaw, J., and Martinez, P. (eds.), *IAU Special Session #5. Astronomy for the Developing*

World. *26th Meeting of the IAU, held 21–22 August, 2006 in Prague, Czech Republic. IAU Special Session No. 5, 2006*. Cambridge, Cambridge University Press. Pp. 135–136.
Soonthornthum, B., 2017. The development of astronomy and emergence of astrophysics in Thailand. In Nakamura and Orchiston, 2017b, 271–290.
Soonthornthum, B., and Orchiston, W., 2021. King Rama IV: astronomer and 'The Father of Thai Science'. In Orchiston and Vahia, 253–284.
Soonthornthum, B., Euarchukiati, V., and Orchiston, W., 2021. The total solar eclipse of 9 May 1929: the British and German expeditions to Pattani in southern Siam. In Orchiston and Vahia, 373–389.
The story of Rama V. n.d. (https://www.costerdiamonds.com/inside-coster/the-story-of-king-rama-v/; retrieved 5 November 2020).
Thai Meteorological Department. n.d. (https://en.wikipedia.org/wiki/Thai_Meteorological_Department; retrieved 5 November 2020).
Thai Navy time service history. n.d. (http://www.hydro.navy.mi.th/time/history.pdf; retrieved 5 November 2020).
TMD [Thai Meteorological Department] History. n.d. (https://www.tmd.go.th/en/aboutus/history.php; retrieved 5 November 2020).
Todd, Sir Charles, 1893. Meteorological work in Australia: a review. In Tate, R., Rennie, E.H., and Bragg, W.H. (eds.), *Report of the Fifth Meeting of the Australasian Association for the Advancement of Science, Held at Adelaide, South Australia, September 4 1893*. Sydney, AAAS. Pp. 246–270.
Tuck, P.J.N., 1995. *The French Wolf and the Siamese Lamb: The French Threat to Siamese Independence*, *1858–1907*. Bangkok, White Lotus.
Udías, A., 2003. *Searching the Heavens and the Earth: The History of Jesuit Observatories*. Dordrecht, Academic Publishers.
Utting, M., 1989. *Cooke's Perth Observatory*. Perth, Perth Observatory.
Utting, M., 1992. *Astronomy in Western Australia. Volume 1: 1896 to 1912*. Perth, Perth Observatory.
Venkateswaran, T.V., 2019. Ragoonatha Charry and his 'scientific' *Pañcāṅga*. In Orchiston, Sule and Vahia, 263–296.
Warren, J.F., 2009. Scientific Superman: Father Jose Algue, Jesuit meteorology, and the Philippines under American rule, 1897–1924. In McCoy, A.W., and Scarano, F.A. (eds.), *Colonial Crucible: Empire in the Making of the Modern American State*. Wisconsin, The University of Wisconsin Press. Pp. 508–519.
Warren, J.F., 2012. Weather, history and empire: the typhoon factor and the Manila galleon trade, 1565–1815. In Wade, G., and Tana, L. (eds.), *Anthony Reid and the Study of the Southeast Asian Past*. Singapore, Institute of Southeast Asian Studies. Pp. 183–220.
Weiderkehr, V.H., 1988. Georg Neumayer und die Grundung eines geophysikalisch-nautischen Observatoriums in Melbourne 1857. In Schroder, W. (ed.), *Past, Present and Future Trends in Geophysical Research*. Bremen-Roennebeck, International Commission on History of AIGA. Pp. 111–125.
Williamson, F., 2015. Weathering the British Empire: meteorological research in the early nineteenth-century Straits Settlements. *British Journal for the History of Science*, 48, 475–492.
Williamson, F., and Wilkinson, C., 2017. Asian extremes: experience, exchange and meteorological knowledge in Hong Kong and Singapore c.1840–1939. *History of Meteorology*, 8, 159–178.
Williamson, F., 2020. An Ocean Apart: Meteorology and the Elusive Observatories in British Malaya. Paper presented at the conference on "Where Science & Empire Met: Observatories in Asia in the Late 19th to Mid–20th Centuries", University of Philippines Diliman, Manila, 27–28 February 2020.
Winichakul, T., 1997. *Siam Mapped: A History of the Geo-body of a Nation*. Honolulu, University of Hawaii Press.
Wood, H., 1958. *Sydney Observatory 1858 to 1958*. Sydney, Government Printer (Sydney Observatory Papers No. 31).

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Wayne has wide-ranging research interests but has mainly published on historic transits of Venus; historic solar eclipses; historic telescopes and observatories; the emergence of astrophysics; the history of cometary and meteor astronomy; the astronomy of James Cook's three voyages to the Pacific; amateur astronomy and the amateur–professional interface; the history of meteoritics; Indian, Southeast Asian and Māori ethnoastronomy; and the history of radio astronomy. Since moving to Thailand in 2013 he has published extensively on aspects of Asian astronomical history.

Recent books include *Exploring the History of New Zealand Astronomy…* (2016, Springer); *John Tebbutt: Rebuilding and Strengthening the Foundations of Australian Astronomy* (2017, Springer); *The Emergence of Astrophysics in Asia …* (2017, Springer, co-edited by Tsuko Nakamura); *Exploring the History of Southeast Asian Astronomy …* (2021, Springer, co-edited by Mayank Vahia) and *Golden Years of Australian Radio Astronomy …* (2021, Springer, co-authored by Peter Robertson and Woody Sullivan). In addition, Wayne has edited or co-edited a succession of conference proceedings. The Asian astrophysics books mentioned above both contain chapters on the astronomical history of Siam/Thailand.

Since 1985 Wayne has been a member of the IAU, and he is the current Immediate Past President of Commission C3 (History of Astronomy). In 2003 he founded the IAU's Historical Radio Astronomy Working Group, and is the current Radio Astronomy Subject Editor of Springer's *Biographical Encyclopedia of Astronomers, Volume 3*. He also founded the IAU Working Group on Historic Transits of Venus, and is the Founding Chair of the History & Heritage Working Group of the SE Asian Astronomy Network and Director of the Historical Section of the Royal Astronomical Society of New Zealand.

In 1998 Wayne co-founded the *Journal of Astronomical History and Heritage,* and was the Managing Editor until 31 July 2022 when he passed ownership of the journal to the University of Science and Technology of China. In 2013 the IAU named minor planet 48471 'Orchiston', and in 2019 he and Dr Stella Cottam were co-recipients of the American Astronomical Society's Donald Osterbrock Book Prize for their 2015 Springer book, *Eclipses, Transits and Comets of the Nineteenth Century: How America's Perception of the Skies Changed.*

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