

The science and practice of Māori astronomy and Matariki

Hēmi Whaanga, Pauline Harris, Rangi Matamua
University of Waikato
Victoria University of Wellington

Abstracts

Ki te iwi Māori me ōna tūpuna, ko ngā hua o te noho tahi, o te āta pānui, o te kōrero anō hoki me ngā whetū, he mea āta tuitui ki te pūtaiao, ki te ahureatanga, ki ngā tikanga aho atua, ki te taiao anō hoki. Ko ngā nekehanga o ngā kāhui whetū he mea āta pānui, ka mutu he whakapono, he mātauranga atu anō hoki tō ia iwi, tō ia takiwā puta noa i a Aotearoa nei mō te ao tukupū. Ko te mātauranga whānui mō te kōkōrangī he mea āta whakaora anō hoki ki ngā kōrero tuku iho, ki ngā tikanga hauhake whenua, ka mutu i āta whakaurua ki roto i ngā tikanga whakatū whare tupuna. Tau atu, tau māi, whakanuia ai te rewanga ake me te tōnga iho o ngā whetū hiahira, ka mutu i kaha whakaatuahia ngā kaupapa katoa o te tuarangi ahakoa pēhea. Mā roto mai i tēnei pepa ka kōrerohia te mātauranga me te pūtaiao mātai arorangi e whai iho nei ki a Matariki, ka tahi, ka rua ka wānangahia te whakarauora haeretanga i ngā tikanga tuku iho e hāngai nei ki taua kāhui whetū me tana pānga nuitanga ki te ahurea o te whenua o nāianeī, o Aotearoa.

For Māori and their ancestors, the results of living with, studying and talking about the stars were woven into science, language, culture, religious practice and environment. The movements of the celestial bodies were studied in great detail, and all tribal groups and regions throughout Aotearoa maintained their own unique beliefs and understandings of the universe. The exten-

sive knowledge of the night sky was embedded into traditional Māori society, preserved in oral tradition, planting and harvesting practices, and incorporated into the building of ancestral houses. Every year, the rising and setting of important stars were celebrated, and all manner of cosmological events were worshipped. In this paper we will discuss the astronomical knowledge and science associated with Matariki (Pleiades) and discuss how the regeneration of the traditional practice associated with this celestial cluster is playing a significant role in the modern cultural landscape of Aotearoa.

Keywords: Indigenous Knowledge; Māori astronomy; Matariki (Pleiades); Systems of time; Maramataka

Māori astronomy

Māori astronomical knowledge was infused across the breadth and depth of Māori society, tradition, knowledge and language (Harris *et al.* 2013; Whaanga & Matamua 2016; Matamua 2017a, 2017b). Connecting observation, cultures, religion, mythology and astrological practices, this knowledge system was transmitted in oral traditions such as *mōteatea* (traditional song), *whakataukī* (proverbs), *karakia* (incantations) and *kōrero tuku iho* (oral tradition). Māori astronomy was also incorporated practically in areas such as the *maramataka* (the lunar calendar), through planting and harvesting practices and the engraving of carving pat-

Correspondence: hemi@waikato.ac.nz



Hēmi Whaanga is an associate professor in Te Pua Wānanga ki te Ao (The Faculty of Māori and Indigenous Studies) at Waikato University. Dr Whaanga has been involved in a range of linguistic, mātauranga Māori, and curriculum projects. He has published in the areas of mātauranga Māori, traditional ecological knowledge, digitisation of indigenous knowledge, language revitalisation, linguistics, language teaching and curriculum development.

Pauline Harris (Ngāti Kahungunu, Rongomaiwahine) is an astrophysicist, researching and sharing Māori knowledge about tātai arorangi (astronomy) and maramataka (Nature's calendar). In the Science and Society programme at Victoria University of Wellington, Dr Harris also teaches about climate change, science and mātauranga Māori, and issues within science that are important to Māori culture, including environmental problems, energy production, genetic engineering, and xenotransplantation.



Rangi Matamua (Tūhoe) is a professor at the University of Waikato, and his research fields are Māori astronomy and star lore, Māori culture, and Māori language development, research and revitalisation. He travels extensively throughout the country giving public lectures about Matariki and Māori Astronomy.

terns and paintings that adorn ancestral houses (Harris *et al.* 2013). Māori astronomy was embedded and encoded into these carvings and integrated into the landscape through place names. Most famously, Māori astronomy is most well-known for its application to celestial navigation that helped the ancestors of the Māori to traverse the Pacific Ocean, one of the largest regions of the earth (Matamua *et al.* 2013; Tuaupiki 2017). Utilising the sky as a roadmap, detailed observations and astronomical knowledge supported the ‘ancestors of the Māori to undertake arguably the most remarkable voyage[s] in the history of humanity ... [O]nce here, elements of the star-knowledge of the central Pacific were adapted to become relevant to these islands and their climate. ... Over the next 800 years, Māori astronomy evolved with the people to become the situationally specific knowledge base that it is today’ (Whaanga & Matamua 2016, p. 60). With a change in location, in particular latitude, new stars became visible and thus new knowledge and understandings about those stars had to be developed.

The movements of the celestial bodies were studied in great detail, their appearance, position, colour and brightness were examined, and their heliacal rising and setting were celebrated. Māori astronomers (*tohunga kōkōrangī*), developed an awareness of the different links between movements of celestial bodies and seasonal patterns in order to ensure food security, and all manner of cosmological phenomena were worshipped, studied and correlated to terrestrial events, and connections were drawn between them (e.g. seasonal changes, the timing of ocean tides, and the nature of comets, eclipses, meteors, and other transient celestial phenomena) (Harris *et al.* 2013; Matamua 2017b). This knowledge was regionally specific and while the stars gave a broad indication as to the season and event, more detailed understanding of the environment was deduced through the lunar calendar, such as the management and harvesting of species and the migration and spawning of animals around the cosmological cycle and seasonally timed rituals (Tāwhai 2013; Timoti *et al.* 2017).

During the 19th century and the early parts of the 20th century, the documentation of Māori traditions, life style, language and customs of the Māori was a preoccupation for many early European ethnographers, missionaries, and historians, with the likes of George Grey (1853, 1857), William Colenso (1868, 1878, 1879), S. Percy Smith (1898, 1913, 1915), John White (1887–1890), members of the Williams family (1906, 1844), James Cowan (1910, 1930), Edward Treagar (1904) and Elsdon Best (Holman 2008; Sissons 2010), leading the way.

Regarded as one of the most important early ethnographers in Aotearoa, Elsdon Best (Te Pēhi) spent much of his time interviewing Māori elders, researching Māori tribal history, and collecting mātauranga Māori (1922a, 1922b, 1922c, 1923, 1924, 1929, 1972). While in the Urewera, Te Pēhi formed a close working partnership with his key informants Tutakangahau of Maungapohatu, Paitini Wi Tapeka, Tamarau Waiari, Te Whenuanui of Tūhoe, and Hamiora Pio of Ngāti Awa, while maintaining his longstanding relationship and roles with the Polynesian Society and the National Museum. Te Pēhi produced a number of important works on various aspects of pre-European Māori life and tribal history, Māori religion and mythology, Māori forest

knowledge, wānanga Māori, but his publication ‘*The Astronomical Knowledge of the Maori Genuine and Empirical*’, has been widely considered, for a long-time, as the leading work on Māori astronomy (Orchiston 2016b). In this publication he pronounced that ‘the available data concerning Maori sky-lore is now exhausted, and this account must be closed. The knowledge gained by us of this subject is meagre and unsatisfactory, but it is now too late to remedy the deficiency’ (Best 1922a, p. 64). This statement, however, was much too presumptuous, for unbeknown to Te Pēhi, the informants that he had interviewed had only shared with him a small portion of knowledge on Māori astronomy.

Over the past three decades, there has been a renaissance in the scientific study of Māori astronomy in a range of areas including reviews on Māori astronomy (Harris *et al.* 2013; Williams 2013; Tuahine 2015; Orchiston 2016b), lists on Polynesian and Māori star names (Johnson *et al.* 2015), accounts on the development of astronomy and emergence of astrophysics in Aotearoa (Hearnshaw & Orchiston 2017), histories of astronomy in New Zealand (Orchiston 2016a), critiques of Polynesian, aboriginal and Māori astronomical perspectives (Orchiston 1996, 2000), the use of astronomy as a cultural experience (Austin 2009), comparative cultural studies of astronomical knowledge (Selin 2000), a discussion on supernovas and meteors (Green & Orchiston 2004; Britton & Hamacher 2014), the application of portable planetariums in the teaching of Māori astronomy (Harris 2017), horticultural and ethnopedological praxis (Roskrige 2011), *waka* navigation (Matamua *et al.* 2013; Tuaupiki 2017), the *maramataka* (Ropiha 2000; Roberts *et al.* 2006; Smith 2011; Tāwhai 2013; Clarke & Harris 2017), *Matariki* and *Puanga* (Matamua 2013; Williams 2013; Rerekura 2014; Matamua 2017a, 2017b), together with a number of popular publications and resources on Māori astronomy (Leather & Hall 2004; Hakaraia 2006, 2008).

The science and practice of Māori astronomy: Matariki

The renaissance in the scientific study of Māori astronomy has developed out of the burgeoning development of Māori-led cross-cultural celebrations and ceremonies of celestial events such as the heliacal rising and setting of *Matariki* (Hakaraia 2006, 2008; Hardy 2012; Matamua 2017a, 2017b). This star cluster, known as the Pleiades elsewhere, has found new status within the cultural and societal landscape of Aotearoa (Hardy 2012). The revival of the *Matariki* celebration had a humble beginning, with small gatherings of people associated with Pipitea marae and Te Papa Tongarewa in Wellington in the 1990s (Hardy 2016). However, by the beginning of the 2000s, *Matariki* celebrations transformed into larger gatherings and events moving from a celebration of Māori culture to one associated with growth, development, and identity (Hardy 2012; Hardy 2016; Whaanga & Matamua 2016). Now, numerous *Matariki* events are held throughout Aotearoa in both the larger cities and smaller communities where ‘people are once again using the pre-dawn rising of this star cluster to foster unity and togetherness. *Matariki* has become part of school curriculum, is included within the structure of city councils and other organisations and is promoted on television, via radio and in print’ (Whaanga & Matamua 2016,

p. 67). We are also seeing *Matariki* embedded into a wide range of art, from *tā moko* (traditional tattooing) to modern art to large scale museum exhibitions.

The *Matariki* cluster is of great significance to many cultures worldwide, is known by many names such as the Pleiades, Seven Sisters, or Messier 45. It is an open star cluster located within the constellation of Taurus with several hundred stars of which only a handful are visible with the naked eye. *Matariki* is often mistakenly translated as little eyes or small eyes, *mata* 'eyes' and *riki* 'small' or 'little', which originates from Te Pēhi (Best 1972) where he describes a literal translation of the word '*Matariki*'. Matamua (2017a; 2017b) describes another account of *Matariki* as a truncated version of the longer name, *Ngā mata o te ariki Tāwhirimātea*, or the eyes of the god *Tāwhirimātea*. He recounts that, in the beginning, *Ranginui* (the Sky Father) and *Papatūānuku* (Earth Mother) were bound together in a tight embrace, where their children were cloaked in perpetual darkness. The children, the pantheon of Gods, eventually agreed, apart from *Tāwhirimātea* the god of winds and weather, to separate their parents as a course of action. *Tāwhirimātea* sought retribution from his siblings and he set forth on a series of attacks against them. His brothers cowered before his wrath except *Tūmatauenga*, the god of war and humanity: a warrior. Following an epic battle, *Tūmatauenga* triumphed, banishing his brother to the sky. Defeated and overcome with sorrow, *Tāwhirimātea* plucked his eyes and cast them into the heavens in a display of rage and contempt towards his siblings and *aroha* (love) for his father. These eyes became the stars of *Matariki*, *Ngā mata o te ariki Tāwhirimātea*. This understanding of the origins of *Matariki*, or *Ngā Mata o te Ariki o Tāwhirimātea* is now gaining traction in mainstream New Zealand consciousness, however much misrepresentation of the names' meaning is still perpetuated nation-wide.

Matariki is also known by other names including *Te Huihui o Matariki* (the cluster/ assembly of *Matariki*), *Te Tautari-nui-o-Matariki* (*Matariki* fixed in the heavens), *Tāriki* (an abbreviation of *Matariki*), *Aokai* (denoting its connection with food), *Hoko/Hokokūmara* (describing its influence over the growing of *kūmara*), and three further names (*Mataroa*, *Matarohaki*, and *Matawaia*), which were suggested by Te Pēhi as possible names (Best 1910). The name *Matariki* is used to describe the entire star cluster, with nine of the major stars in *Matariki* having their own individual names. They are *Tupuānuku* (*Pleione*), *Tupuārangi* (*Atlas*), *Waiti* (*Maia*), *Waitā* (*Taygeta*), *Waipunarangi* (*Electra*), *Ururangi* (*Merope*), *Pōhutukawa* (*Sterope*), *Hiwa-i-te-rangi* (*Calæno*) and *Matariki* (*Alcyone*). *Matariki* was taken by *Rehua* (*Antares*) as a wife and she gave birth to eight children (five daughters and three sons). *Rehua*, a paramount chief, is connected with medicine and healing and *Matariki* to well-being, good fortune and health, and 'it is within both *Rehua* and *Matariki* that knowledge of well-being and medicine exists, and both have the power to heal' (Matamua 2017b, p. 26). Although there are a number of accounts that recount *Matariki* as a mother to seven daughters, seven sisters, or a flock of birds, these are thought to originate from Greek myth where Māori understandings of *Matariki* over time have merged with Greek myth (Matamua 2017b) and perpetuated as fact.

Within Māori astronomy, many stars not only had an identity associated with them but also had a specific purpose or role intrinsically connected to the Māori world. Within *Matariki*, each of these stars represented either a food, a source or a weather occurrence, the dead or the promise of a prosperous year (similar to the notion of making a new year's resolution or wishing upon a star). *Pōhutukawa* is a female, the eldest and she is associated with the dead who have passed since the last heliacal rising of *Matariki*. *Tupuānuku* is female and she is connected with food grown in the earth. *Tupuārangi* is male and he embodies the food that comes from the sky, including the fruit from trees and birds. *Waiti* is female and she holds the essence of food found in fresh water and *Waitā* is male and he holds the essence of the food in salt water. *Waipunarangi* is female and she is connected with rain and *Ururangi* is male and he is connected to the nature of winds for the year. *Hiwa-i-te-rangi* is female and the youngest of this celestial family. She is associated with the promise of a prosperous year. *Matariki* is the mother and the conductor of the entire cluster (Matamua 2017b).

Overlapping with the growth in *Matariki* celebrations is the regeneration, by a small group of practitioners, in a number of traditional ceremonies that coincide with the heliacal rising of *Matariki*: '*Te taki mōteatea*' (reciting of laments) and '*Whāngai i te hautapu*' (to feed with a sacred offering). These ceremonies, led by Professor Rangi Matamua at Waikato University, are being analysed and reinvigorated by a group of young *tohunga* called *Te Matapuenga*, a group established by the language, *tikanga* and *karakia* expert, Professor Pou Temara. Since 2017, practitioners and followers of the ceremony ascend before dawn in the *Tangaroa* lunar phase of the month *Pipiri* to view the heliacal rising of *Matariki*. Once ascended, the practitioners prepare food that corresponds to each of the domains of *Matariki*. The food is placed at an altar and ceremony is conducted with *karakia* and chants. During this ceremony a reading of the bounty of the year is conducted, the names of the dead of the year are recited and released (*Te taki mōteatea*), and the smoke from the food is offered to the cluster as sustenance (*Whāngai i te hautapu*). The regeneration of this practice associated with *Matariki* ceremony is in stark contrast to many of the celebrations that continue to be conducted nation-wide. The direction of this ceremony towards an honouring of *Matariki* via ceremony is a direction that many Māori are signalling favourably towards (Hardy & Whaanga 2019).

Matariki: Systems of time, the politics of time, and calendrical systems

There are a number of beliefs, ideas and applications associated with *Matariki*. *Matariki* is many things for many people: it has a spiritual dimension, it has a community and cultural dimension, but what is often overlooked and misunderstood, more than any other element, is its association with time; in particular, its connection to Māori divisions of time. The Māori division of time follows a stellar lunar calendar, whereby predominantly heliacal risings of stars or sometimes settings are used as indicators of specific times of the year, with a lunar cycle playing another layer of time increment. These stars could indicate, for example, a month or season of the year. For *Matariki*, probably the most crucial

element missing from its application in a modern context is its role in regulating our yearly cycle, especially because we no longer follow a traditional lunar calendar for our everyday activities.

Indigenous concepts of time, calendar systems, seasonality, rituals, and the rhythms of nature are intrinsically intertwined. Māori, similar to other Indigenous peoples, developed a complex time system integrating celestial, environmental and ecological occurrences to track time and seasonality. The movement of the sun, moon and stars, were used as clocks to regulate the timing of agricultural, fishing and hunting activities, and rituals. This division of time falls under the calendar system known as *maramataka* (Roberts *et al.* 2006; Best 1922b; Ropiha 2000; Tawhai 2013). The *maramataka* is a multilayered time system that utilises observations from the celestial such as the phases of the Moon and the sightings of certain stars, to ecological and environmental indicators such as the flowering of certain plants and occurrence of particular weather patterns (Clarke & Harris 2017).

The use and practice of the *maramataka* has changed as part of the process of colonisation. The move to reform Indigenous time was part of a broader agenda to interrupt 'the cycles of Indigenous and local seasons and calendars, and replacing them with the coloniser's rituals and routines, along with a new calendar for counting the days, months and years ...' (Nanni 2012, p. 3). This colonial-settler agenda sought to alter time as one of the fundamental tenets of Indigenous culture. Calendar reform is closely aligned with geopolitical movements, the role of empire, ecclesiastical control and power (Nanni 2012). As the Gregorian calendar was introduced by Pope Gregory XIII in 1582 to replace the Julian calendar, the same calendrical system was used by European settlers and missionaries in Aotearoa as a colonial act to target the minds, culture and the timing mechanisms of Māori. Māori soon shifted away from following and celebrating traditional Māori months and started to apply and even infuse Māori time within the Gregorian cycle of 365¼ day calendar system including its months, the seven-day week, and the 24-hour clock. The observation of the movements of the celestial bodies and ecological indicators was replaced by colonial timekeepers such as clocks and watches and a calendar based on the movements of the sun (Roberts *et al.* 2006).

Accompanying the demise of the use of *maramataka* and astronomical knowledge, was the devastating loss of land, language, and cultural practices led by successive policies of assimilation and integration, urbanisation, and restricted access to key resources (Walker 2004). These factors impacted profoundly on Māori cultural norms, collectivism, language, and the knowledge systems that were woven into the practice of Māori astronomy and the *maramataka* (Whaanga & Matamua 2016). As a result, the celebration of *Matariki* had almost disappeared as a recognisable part of the cultural landscape of Aotearoa by the middle of last century. Driven by the impending threat to the future of Māori, a series of Māori-led campaigns, petitions, and claims were undertaken in the late 70s and 80s to revitalise the Māori language, its knowledge and cultural systems, focusing on issues such as the Treaty of Waitangi, Māori land rights, language and

culture, and racism (Harris 2004; Walker 1984, 2004).

As part of the cultural renaissance of reinvigorating the use of *maramataka* and Māori astronomical knowledge with star and lunar indicators, the recovery has had many challenges. In particular, in order to decolonise the calendar system and return to a traditional calendar system we have had to step away from the need to resolve and merge the Gregorian calendar with the *maramataka*. This has been due to how the Gregorian calendar has evolved away from its traditional origins. The evolution of this calendar has involved adding and subtracting days to the original true lunar months, giving 28–31 days in the Gregorian months, which could then be added to give a solar year of 365 days. In addition, the leap year is used to readjust the calendar to fit the solar year approximately every 4 years. Also, what is not commonly known is that additional seconds are added where needed to keep Coordinated Universal Time (UTC) in alignment with the actual length of time it takes the Earth to rotate (Frankston 2017). With such a number of adjustments, the reconciling of the Gregorian calendar with the *maramataka* is somewhat futile and what is needed is to understand the *maramataka* as its own independent system.

The stellar component of the *maramataka*, which includes *Matariki*, is a regulator for the Māori year and it was a cyclic indicator that determined when the Māori year commenced. Māori also traditionally followed a lunar component of the calendar, which is 354 days long and is based upon the cycles of the moon phases (synodic months). Thus, there is an 11-day difference between the Māori lunar calendar and the 365 day year, 12 months western solar calendar that we currently follow. Over a two-year cycle this difference becomes 22-days, over three-years it results in 33-days and therefore there becomes a full month variation between a lunar and solar calendar.

Māori understood the subtleties and importance of this relationship and they practised a system to ensure that they harmonised with the cycle of the year and the seasons. This was done every three years, when they would insert an extra month into their calendar system. This month was known as *Ruhanui* or the listless or lazy month. The use of what is known as an intercalary month was a common practice world-wide. Early uses of an additional month can be found in calendars of the Greeks (Van der Waerden 1960), Hebrews (Segal 1957), and Chinese (Aslaksen 2010; Martzloff 2016) amongst many others. These calendars place the insertion of a 13th month at various stages during their calendars with varying degrees of accuracy. For Māori, however, the intercalary month was more approximate and precision was less of a concern with a focus more on what works. Other systems around the world have adopted the metotonic scale that places 7 extra months over a 19-year time scale.

For Māori, the indicator of when to place the intercalary month was related to the appearance of the constellation *Pipiri*, which are two stars in the constellation of Aries known as Sheratan and Hamal. These two stars for Māori are called *Pipiri* and *Ruhanui*. For many Māori constellations the name of one particular star in the group will also be the name of the entire constellation. Hence *Pipiri* is the name of the constellation and also the name of a particular star (Sheratan) in the constellation. These two stars are referred

to as twins, as they appear in close proximity to each other and rise very near each other in the night sky. In the Māori calendar system, the months also often carried the names of stars. For example *Pipiri* rises in the eastern-sky in late May. When the first star in the constellation of *Pipiri* rose, it was taken as a sign that the winter month was upon us and the year was about to start, it also indicated that the following month after the sighting would be *Pipiri*, which is named after the constellation. As the *maramataka* is a solar-luni calendar, many events would also coincide with a particular moon phase. In the case of the new year, as soon as *Matariki* was seen in the sky during the month of *Pipiri* our ancestors would wait until its sighting coincided with a particular lunar phase of *Tangaroa* (the last quarter). Thus, the Māori new-year begins when *Matariki* is seen in the sky on the last quarter of the first month of the year, called *Pipiri*.

When following both a lunar and stellar cycle, as described earlier, 12 lunar months will add up to only 354 days and will leave a remainder of 11 days till the solar year is completed. The implication of this is that the lunar phase *Tangaroa* will be occurring 11 days earlier than the previous year. When observing the night sky, the 11-day shift between lunar and stellar cycles across the year will thus mean that each year *Matariki* would appear lower and lower in the sky on the horizon at the time of *Tangaroa* (last quarter phase) as the years progress (see Figure 1).

As heliacal risings of stars occur early in the morning before the sun rises, the closer the star is to sun below the horizon, the more difficult it is to see. Given that *Matariki* is a 3rd magnitude star, in order to view its heliacal rise with the naked eye, the cluster will need to be at least 5 degrees above the horizon while the sun is at least 16 degrees below (Matamua 2017a). As *Matariki* is supposed to occur during the month of *Pipiri* in *Tangaroa*, eventually the 11-day slippage will be so far out that *Matariki* will not be visible at that time. When *Matariki* was not visible during the *Tangaroa* phase of the month of *Pipiri*, *Pipiri* would become a double month. This is when the intercalary month known as *Ruhanui* would be applied and Māori would follow the second star in *Pipiri* to determine when our new year would commence. Figure 1 shows the position of *Matariki* in the early predawn sky in the month of *Pipiri* on the first phase of *Tangaroa* for the years 2018 (Fig 1a), 2019 (Fig 1b), 2020 (Fig 1c) and 2021 (Fig 1d). In order to ensure visibility, the times chosen were for when the sun is at least 16 degrees below the horizon. For 2018, 2019, and 2021 *Matariki* is clearly seen above 5 degrees; however, for 2020, *Matariki* is below the 5 degree limit and thus is not visible. Therefore in 2020 an intercalary month needs to be inserted following *Pipiri* and is called *Ruhanui*. Thus, when *Matariki* is not visible because of the ongoing 11-day slippage every year, an additional month is added in the first month of the Māori new year and the whole cycle resets itself.

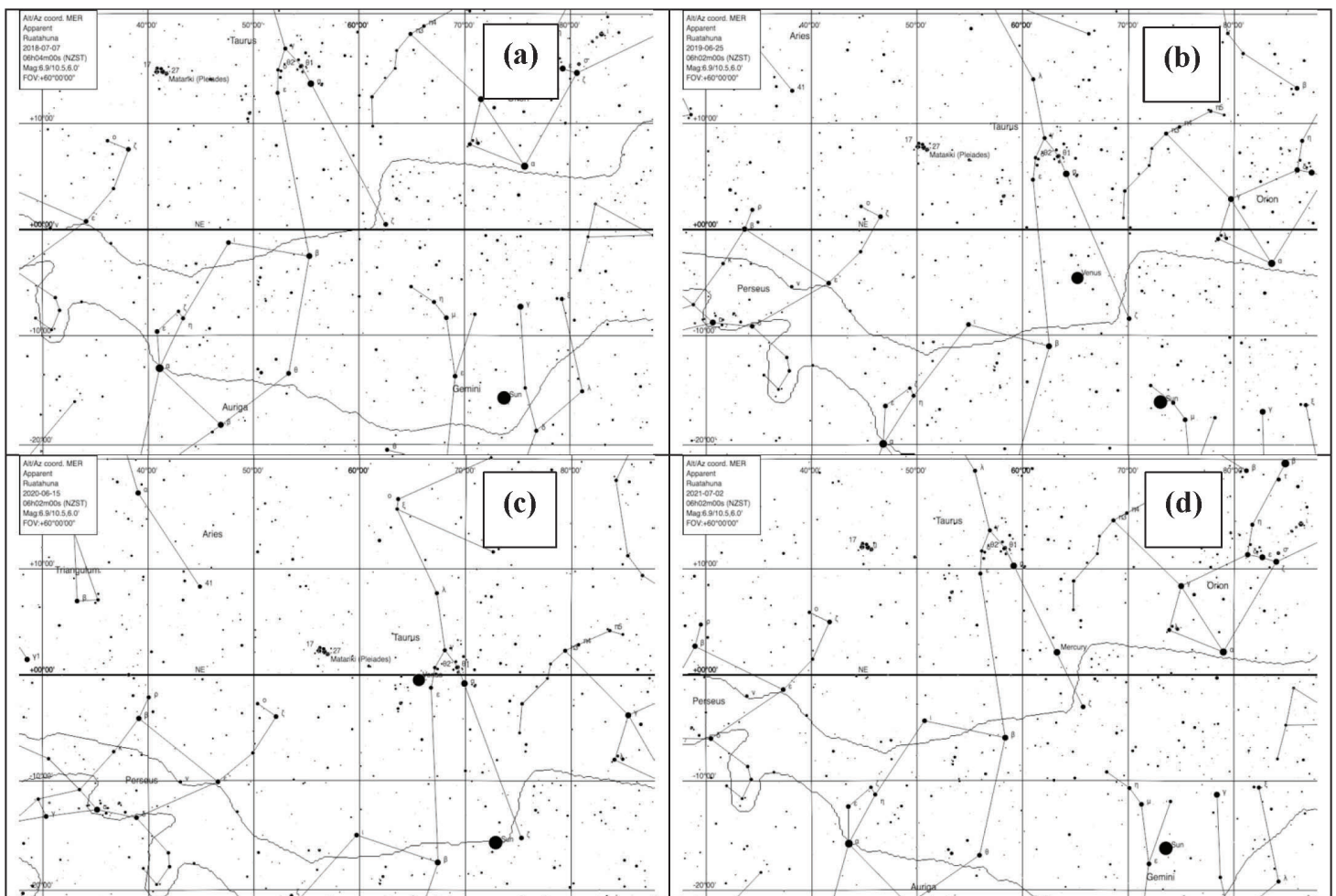


Figure 1a–1d: Star maps where *Matariki* is present in the pre-dawn sky in the moon phase *Tangaroa-a-mua* in the month of *Pipiri* for 2018–2021 (after Matamua 2017a). The sun is located at approximately 16 degrees below the horizon in each map.

With many people wanting to engage in *Matariki* celebration, much of the understanding around this concept has become muddled and confused in the public domain. As many try to fit the timing of *Matariki* within the Gregorian system, these two completely different time-keeping systems clash and there remains much confusion about when *Matariki* is visible and when it should be celebrated. Without the understanding of such intricacies of the intercalary month information regarding the timing of *Matariki* becomes incorrect. Attempting to reconstitute and reconfigure our sighting of *Matariki* with a Gregorian calendar is fundamentally flawed and continues to cause confusion when trying to understand the internal workings of a Māori system of time.

Conclusion

This paper has highlighted a small portion of the extensive scientific and astronomical knowledge base that our ancestors infused across all facets of Māori society. Over the past three decades, there has been a renaissance in the scientific study of Māori astronomy, with the celestial cluster of *Matariki* playing a significant role in the regeneration of Māori astronomy, science and traditional practice in Aotearoa. A key area that has enabled the growth of this knowledge has been government funding that has supported the myriad of projects and initiatives driven by Māori astronomy practitioners and organisations. In the past 15 years there has been a shift to engage with policies such as Vision Mātauranga (VM) and Mātauranga Māori more effectively in the research, development and economic space (Ministry of Research, Science and Technology, MORST 2007). The VM policy was developed in 2005 by MORST to engage and include Māori aspirations into these spaces, with its aim being to unlock the innovative potential of Māori knowledge, resources, and people in order to assist New Zealanders in creating a better future (MORST 2009). For many years, however, the way in which Māori have been engaged with via the VM policy has been tokenistic. Nonetheless, in more recent times, a number of initiatives and accountability to strengthen Māori inclusion and leadership have been implemented through placement programmes and research funding such as Curious Minds from the Ministry of Business, Innovation, and Employment (MBIE), which has opened up the door to enable Māori science to begin to grow and flourish. From these foundations the Māori astronomy space has grown, supported by funds such as the Royal Society of New Zealand Marsden Fund, MBIE, Te Puni Kōkiri, Te Taura Whiri, Te Māngai Pāho, and Ngā Pae o te Māramatanga.

The power of Māori astronomy is that it connects in a multifaceted way; from outreach into communities working with *rangatahi* (youth) to inspire them to realise their potential and imbue ancestral knowledge that has been hidden from them, to the development of new practitioners in rituals and practices around *Matariki*, to the creation of practitioners of *maramataka* to monitor the environment, ecological systems and well-being of themselves. The breadth of reach of Māori astronomy now is reaching millions of people and is growing in popularity every day. With over 20,500 followers for the *Living by the Stars* series, and over a million views of the popular series, the phenomenon

that is occurring is unprecedented. Over the past 20 years researchers and practitioners have been actively sharing and growing the navigation, Māori astronomy and *maramataka* space by engaging the public in over 1000 talks, roadshows to over 8000 people, outreach to over 10,000 Māori and Pacific *rangatahi* and museum exhibitions that attracted more than 315,000 visitors.

Nevertheless, as this renaissance and revitalisation continues, *tohunga kōkōrangī*, navigators, Māori researchers, practitioners, and Māori communities face a number of challenges to decolonise and reconcile many facets of this knowledge base. The challenge for these groups lies in bringing together the collective knowledge, experiences, and voices to ensure its authenticity and legitimacy for future generations of aspiring Māori astronomers.

References

- Aslaksen, H. 2010. *The Mathematics of the Chinese Calendar*. Department of Mathematics, University of Singapore, Singapore, Malaysia.
- Austin, M. 2009. From Ancient to Modern: The role of astronomy as a cultural experience. *Proceedings of the International Astronomical Union* 5(S260): 225–228.
- Best, E. 1910. Maori star names. *Journal of the Polynesian Society* 19(2) 97–99.
- Best, E. 1922a. *The astronomical knowledge of the Maori, genuine and empirical: Including data concerning their systems of astrology, astrolatry, and natural astrology, with notes on certain other natural phenomena*. Govt Print., Wellington.
- Best, E. 1922b. *The Maori division of time*. Govt Print., Wellington.
- Best, E. 1922c. *Some aspects of Maori myth and religion*. Govt Print., Wellington.
- Best, E. 1923. *The Maori school of learning : its objects, methods, and ceremonial*. Dominion Museum, Wellington.
- Best, E. 1924. *The Maori*. Board of Maori Ethnological Research for the Author and on behalf of the Polynesian Society, Wellington.
- Best, E. 1929. *Fishing methods and devices of the Maori*. Dominion Museum, Wellington.
- Best, E. 1972. *Tuhoe, the children of the mist; a sketch of the origin, history, myths and beliefs of the Tuhoe tribe of the Maori of New Zealand, with some account of other early tribes of the Bay of Plenty district*. Published for the Polynesian Society by A.H. & A.W. Reed, Wellington.
- Britton, T.R., Hamacher, D.W. 2014. Meteor Beliefs Project: Meteors in the Māori astronomical traditions of New Zealand. *WGN – Journal of the International Meteor Organization* 42(1): 31–34.
- Clarke, L., Harris, P. 2017. Maramataka. Pp. 129–135 in Whaanga, H., Keegan, T.T., Apperley, M. (Eds) *He Whare Hangarau Māori - Language, culture & technology [Ebook]*. Te Pua Wānanga ki te Ao, Te Whare Wānanga o Waikato, Hamilton, New Zealand.
- Colenso, W. 1868. On the Maori races of New Zealand. *Transactions and Proceedings of the New Zealand Institute* 1: 339–423.
- Colenso, W. 1878. Contributions to a better knowledge of the Maori race. Part I: Legends, myths and fables; The ideality of the ancient New-Zealander. *Transactions and Proceedings of the New Zealand Institute* 11: 77–106.
- Colenso, W. 1879. Contributions towards a better knowledge of the Maori race. Part II: On the ideality of the ancient New-Zealander; Proverbs and proverbial sayings. *Transactions and Proceedings of the New Zealand Institute* 12: 108–147.
- Cowan, J. 1910. *The Maoris of New Zealand*, Whitcombe & Tombs, Christchurch, New Zealand.
- Cowan, J. 1930. *The Maori, yesterday and today*, Whitcombe & Tombs, Christchurch, New Zealand.
- Frankston, B. 2017. *The Problem of Leap Seconds*. In: Arias E., Combrinck L., Gabor P., Hohenkerk C., Seidelmann P. (Eds) *The Science of Time 2016. Astrophysics and Space Science Proceedings, vol 50*. Springer, Cham.
- Green, D.A., Orchiston, W. 2004 In search of Mahutonga: A possible supernova recorded in Maori astronomical traditions? *Archaeoastronomy* 18: 110–113.

- Grey, G. 1853. *Ko nga moteatea, me nga hakirara o nga Maori: He mea kohikohi mai*. Robert Stokes, Wellington.
- Grey, G. 1857. *Ko nga whakapepeha me nga whakaahuareka a nga tipuna o Aotea-roa: Proverbial and popular sayings of the ancestors of the New Zealand race*. Saul Solomon & Co., Cape Town.
- Hakaraia, L. 2006. *Celebrating Matariki*. Reed, Auckland.
- Hakaraia, L. 2008. *Matariki: The Māori New Year*. Raupo, North Shore, Auckland.
- Hardy, A. 2012. Re-designing the national imaginary: the development of Matariki as a contemporary festival. *Australian Journal of Communication* 39(1): 103–119.
- Hardy, A. 2016. Matariki Hanganui: Te Papa Tongarewa and the celebration of Matariki, the Māori New Year. *Material Religion* 12(3): 396–398.
- Hardy, A., Whaanga, H. 2019. Using the stars to indigenize the public sphere: Matariki over New Zealand. *Religion* 10(7): 431.
- Harris, A. 2004. *Hikoi: Forty years of Māori protest*. Huia, Wellington.
- Harris, P. 2017. Portable planetariums in the teaching of Māori astronomy. Pp. 136–148 in: Whaanga, H., Keegan, T.T., Apperley, M. (Eds) *He Whare Hangarau Māori – Language, culture & technology [Ebook]* Te Pua Wānanga ki te Ao, Te Whare Wānanga o Waikato, Hamilton, New Zealand.
- Harris, P., Matamua, R., Smith, T., Kerr, H., Waaka, T. 2013. A review of Māori Astronomy in Aotearoa-New Zealand. *Journal of Astronomical History and Heritage* 16(3): 325–336.
- Hearnshaw, J., Orchiston, W. 2017. The development of astronomy and emergence of astrophysics in New Zealand. Pp. 581–621 in: Nakamura, T., Orchiston, W. (Eds) *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe*. Springer International Publishing, Cham.
- Holman, J.P. 2008. Elsdon Best, 1856 – 1931. *Kōtāre* 7(2): 93–100.
- Johnson, R.K., Mahelona, J.K., Ruggles, C. 2015. *Nā Inoa Hōkū – Hawaiian and Pacific star names*, Ocarina Books, Bognor Regis, UK.
- Leather, K., Hall, R. 2004. *Tātari arorangi, Māori astronomy: Work of the gods*. Viking Sevenses NZ, Paraparaumu, New Zealand.
- Martzflof, J.-C. (Ed.) 2016. *Astronomy and Calendars – The Other Chinese Mathematics*. Springer Berlin, Heidelberg.
- Matamua, R. 2013. Matariki – The Seven Sisters. Pp. 23–27 in: *Take a closer look: New Zealand stories in stamps*, New Zealand Post, Wellington.
- Matamua, R. 2017a. *Matariki – te whetū tapu o te tau*. Huia, Wellington.
- Matamua, R. 2017b. *Matariki – the star of the year*. Huia, Wellington.
- Matamua, R.L., Harris, P., Kerr, H. 2013. Māori Navigation. Pp. 28–33 in: Christie, G., Creagh, J. (Eds) *New Zealand Astronomical Society Yearbook 2013*. Stardome Observatory Planetarium, Auckland.
- Ministry of Research, Science and Technology 2007. *Vision Mātauranga*. Retrieved from <https://www.mbie.govt.nz/dmsdocument/1269-vision-matauranga-booklet>
- Ministry of Research, Science and Technology 2009. *Evaluation of Vision Mātauranga*. Retrieved from <https://thehub.sia.govt.nz/resources/evaluation-of-vision-matauranga-and-the-maori-knowledge-and-development-output-class/>
- Nanni, G. 2012. *The Colonisation of Time: Ritual, routine and resistance in the British Empire*. Manchester University Press, Manchester, UK.
- Orchiston, W. 1996. Australian Aboriginal, Polynesian and Maori astronomy. *Astronomy Before the Telescope*, pp. 318–328.
- Orchiston, W. 2000. A polynesian astronomical perspective: The Maori of New Zealand. Pp. 161–196 in: Selin, H., Sun, X. (Eds) *Astronomy across cultures: The history of non-Western astronomy*. Kluwer Academic Publishers, Dordrecht; Boston.
- Orchiston, W. (Ed.) 2016a. *Exploring the history of New Zealand Astronomy*. Springer International Publishing, Heidelberg; New York; Dordrecht; London.
- Orchiston, W. 2016b. The skies over Aotearoa/New Zealand: Astronomy from a Māori Perspective. Pp. 33–88 in: Orchiston, W. (Ed.) *Exploring the history of New Zealand Astronomy*, Springer International Publishing, Heidelberg; New York; Dordrecht; London.
- Rerekura, S. 2014. *Puanga: Star of the Māori New Year*. Te Whare Wananga o Ngāpuhi-nui-tonu, Auckland.
- Roberts, M., Weko, F., Clarke, L. 2006. Maramataka : the Māori moon calendar. *AERU Research Report 345*. Lincoln University, Canterbury, New Zealand.
- Ropiha, J. 2000. Traditional ecological knowledge of the Maramataka: The Māori lunar calendar, Thesis, Victoria University of Wellington.
- Roskruge, N. 2011. Traditional Maori horticultural and ethnopedological praxis in the New Zealand landscape. *Management of Environmental Quality: An International Journal* 22(2): 200–212.
- Segal, J. 1957. Intercalation and the Hebrew calendar. *Vetus Testamentum* 7(3): 250–307.
- Selin, H. 2000. *Astronomy Across Cultures: The History of Non-Western Astronomy*. Springer Netherlands, Dordrecht.
- Sissons, J. 2010. *Best, Elsdon*. Te Ara – the Encyclopedia of New Zealand, <https://teara.govt.nz/en/biographies/2b20/best-elsdon> (accessed 9 March 2020).
- Smith, S.P. 1898. *Hawaiki: The whence of the Maori; with a sketch of Polynesian history*. Whitcombe & Tombs, Wellington.
- Smith, S.P. (Translator) et al. 1913. *The Lore of the Whare-waananga, or, Teachings of the Maori college on religion, cosmogony and history: Vol 1: Te Kauwae-runga, or 'things celestial'*, Printed for the Polynesian Society by T. Avery, New Plymouth, New Zealand.
- Smith, S.P. (Translator) et al. 1915. *The Lore of the Whare-waananga, or, Teachings of the Maori college on religion, cosmogony and history: Vol 2: Te Kauwae-raro, or 'things terrestrial'*, Printed for the Polynesian Society by T. Avery, New Plymouth, New Zealand.
- Smith, T. 2011. *Traditional Māori growing practices*, Te Atawhai o te Ao, Wanganui.
- Tāwhai, W. 2013. *Living by the moon: Te maramataka a Te Whānau-ā-Apanui*. Huia, Wellington.
- Timoti, P., Lyver, P.O'B., Matamua, R., Jones, C., Tahi, B. 2017. A representation of a Tuawhenua worldview guides environmental conservation. *Ecology and Society* 22(4): 20.
- Tregear, E. 1904. *The Maori race*. A.D. Willis, Wanganui.
- Tuahine, H. 2015. *Te tāhū o Ranginui: Whakatūria te whare kōkōrangi*. Thesis, University of Waikato.
- Tuaupiki, J. 2017. *E kore e ngaro, he takere waka nui: Te mātauranga whakaterere waka me ōna take nunui*. Thesis, University of Waikato.
- Van der Waerden, B. 1960. Greek Astronomical Calendars and their Relation to the Athenian Civil Calendar. *Journal of Hellenic Studies* 80: 168–180.
- Walker, R. 1984. The genesis of Maori activism. *Journal of the Polynesian Society* 93(3): 267–282.
- Walker, R. 2004. *Ka whawhai tonu mātou: Struggle without end*. (Revised edn) Penguin, Auckland.
- Whaanga, H., Matamua, R. 2016. Matariki tāpuapua: Pools of traditional knowledge and currents of change. Pp. 59–70 in: Robertson, M., Tsang, P.K.E. (Eds) *Everyday knowledge, education and sustainable futures: Transdisciplinary research in the Asia/Pacific Region*. Springer, Singapore.
- White, J. 1887–1890. *The ancient history of the Maori, his mythology and traditions (Vols 1–6)*. Govt Print., Wellington.
- Williams, H.W. 1906. Maori bird names. *Journal of the Polynesian Society* 15(4): 193–208.
- Williams, J. 2013. Puaka and Matariki: The Māori New Year. *Journal of the Polynesian Society* 122(1): 7–19.
- Williams, W. 1844. *A dictionary of the New Zealand language*. Church Missionary Society, London.